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HEALTHFUL LIVING

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HEALTHFUL LIVING

BASED ON THE ESSENTIALS OF PHYSIOLOGY FOR HIGH SCHOOL PUPILS

BY

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INTRODUCTION

In writing this book, I have been guided by two considerations: first, to present the essentials of physiology for the high school pupil in a form that would provide motives and material that would enable him to interpret intelligently conditions underlying the problem of effective living, and second, to limit the technical discussion without making the subject matter worthless as a scientific text, incapable of providing the background necessary to secure the first consideration.

As regards the limiting of material, it is evident that the selection of what to give and what to omit is a matter of judgment on the part of the author. If that judgment is to be approved by the educational world interested, then the anatomy should have a definite relation to the physiology, and the physiology, although it may give incidentally a scientific basis for more advanced study, should be determined by the larger question of usefulness in understanding essential life processes.

The material and the method of presentation have been tried out for several years with many students and there is reason for feeling that a proper and satisfactory selection of physiologic facts and principles has been made.

It is interesting to note that at one time physiology in the schools was merely the teaching of anatomy. "How many bones in the skeleton?" was a typical question. As the texts improved and the method changed, function was emphasized, and in most texts to-day, the presentation of

function is the goal of endeavor. It should be remembered, however, that knowledge of the structure and function of the body is of value in proportion as it helps the boy or girl to live a finer and more vigorous life, or as it lays the foundation for further study in this field. As regards these values, it may serve effectively to teach not only hygiene, but also social science and ethics.

The study of physiology should arouse interest in health in the student and provide guidance for intelligent care of the body. One effect of civilization on the race is that health is increasingly harder to maintain. The gradual but pronounced change in the character of our food, the increasing emphasis laid upon studies, the prevalence of bad housing conditions, the increase in sedentary occupations, and the enforced use of the transportation facilities are a few of the forces arrayed against the maintenance of health. The school does not stand alone and unrelated to these problems, and physiology to be of most service must help to educate the child in the nature of the human body and the dangers that confront its growth, development, and efficiency.

With this object in mind, distinct emphasis is given the application of the physiological fact to the life of the reader. Therefore, relatively little space is devoted to the study of the mechanism of the eye and ear; but the physiology of exercise is stated prominently, both in text and in illustration. The wisdom of such a course will be clear to every one whether he judges by the standards of "pure science" or by those of "applied science."

Spirited questions, which should suggest many others of similar character, are placed at the end of chapters. There are numerous laboratory experiments; most of these require only the simplest apparatus or none at all. The text is not impaired if the experiments are not performed, but its value is increased by the demonstration of both structure and function. At the close of each chapter is a glossary of technical

terms used in that chapter. There is no thought of doing away with the need for consultation or reference books; they are always necessary, and the brief glossary should stimulate to greater use of dictionary and encyclopedia.

To acknowledge the service of those who have contributed in the preparation of this book, gives me especial pleasure. The organization is based partly on the plan of Coleman's *Elements of Physiology*. All rights in that work have been purchased by the publishers and this new book is offered to the school public without apology for similarities or identities, which are many. The task was to remodel a structure that had been very valuable but was now in need of repairs. The repairs have been made but it would ill become me to deny the old in my enthusiasm for the new.

To Miss Marguerite Smith for the picture of girls' athletics, to Miss Mary Gross for excellent illustrations of posture, to Dr. Frank S. Matthews for the splendid pictures of adenoid deformity, to Dr. Thomas D. Wood for numerous health essentials which he has proposed, I desire to express my thanks.

Students, instructors and friends who have gone over this subject with me share with me whatever merit the book may have, but I desire especially to acknowledge the inspiration and help of Professor Henry Carr Pearson, principal of the Horace Mann School.

The criticism and suggestions of Professor Edward Lawrence Hall-Quest, of the University of Cincinnati, have been valuable indeed. Professor Hall-Quest has read the entire manuscript, correcting mistakes and revising statements. Numerous conferences with Professor William Paxton Burris, Dean of Teachers College of the University of Cincinnati have resulted in substantial aid in preparing the manuscript.

Credit should be given to the Harvard Apparatus Co., The Metropolitan Life Insurance Co., The American Posture

League, and The Scientific Temperance Federation for the privilege of reproducing illustrations that have appeared in other publications.

With such an indebtedness, I hesitate to call the book my own. However, I am glad to owe something to all of these.

J. F. W.

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HEALTHFUL LIVING

CHAPTER I

THE CELLS OF THE BODY

I. The Cell, the Unit of Structure.
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II. The Origin of Cells.

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The cell, the unit of structure. — A brick wall is constructed from bricks. Assembled in a certain order, they are the parts which compose the wall. It makes no difference whether the brick is round, square, or irregular, whether it is painted red, green, or blue; it remains, in all cases, the unit out of which the wall is built. Consequently we speak of the brick as being the unit of structure of the wall (Fig. 1, A). In similar fashion, all forms of life are composed of cells. Plants and animals are both constructed from cells. They may vary in shape, size, color, and activity, but, nevertheless, they are to be considered as the units of structure. These units are so small that they can be seen only by means of the microscope, but when we look

at them through this instrument, we notice that they are as definite in shape as the bricks in a brick wall (Fig. 1, C).

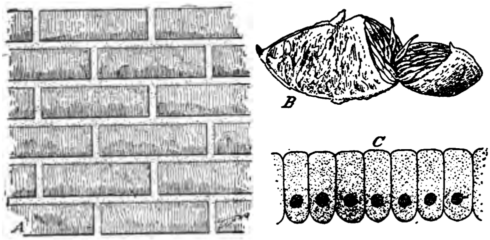

FIG. 1. — *A*, brick wall; *B*, segment of orange; *C*, cells from stomach. The cell is the unit of structure. Relative size is not shown. The cells in *C* are much smaller than the cells in *B*.

The cells of plant and animal are not hard and solid as bricks are. On the contrary, they are soft and liquid. It is quite common to think of an orange as a solid substance, and yet the orange is composed of cells which are filled with a liquid, the juice. If we break open the segment of an orange, we can see the cells with the unaided eye, and if we prick one of them the juice will run out (Fig. 1, B).

*Protoplasm.** — The liquid substance of which the body cell is made is called *protoplasm*, and this name is applied to the cell substance of both animals and plants. Workers with the microscope, many years ago, found that plant and animal tissues are composed of cells, and that the liquid in the cells is of more importance than the walls which the protoplasm builds around itself.

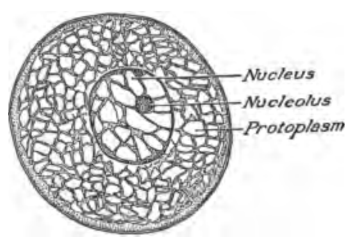

FIG. 2. — Diagram of a cell. Showing that protoplasm has an intricate structure; in this case it appears somewhat like honeycomb.

We should not think because we use the same name, protoplasm, for the substance forming the cellular material of both plants and animals,

* Words marked with a star * are defined in the glossary at the end of each chapter.

that its chemical composition is always the same (Fig. 2). It is best to think of it as a substance that makes possible the life and activity of the cell rather than as a substance that has definite and fixed chemical properties. Furthermore, it is important to remember that the composition of protoplasm varies in the same cell according to many factors. Exercise, food, fresh air, alcohol, and disease cause changes in the protoplasm. Some of these changes are favorable. Can you name, from the above, the factors which cause unfavorable changes? Physiology is the study of the way this protoplasm acts in the cells of the body.

Nucleus. — A living cell has two essential parts. One is a small mass or globule* of protoplasm, and the other is a small body within the mass of protoplasm, called the *nucleus** (Fig. 2). There are two other parts of less importance. Within the nucleus there may be a small body, called the *nucleolus,** and usually the protoplasm has a membrane surrounding it, called the *wall.* The nucleus is the vital part of the cell. If a cell is divided, that portion containing the nucleus alone survives. After they lose their nucleus, the red cells of the blood live only a few days.

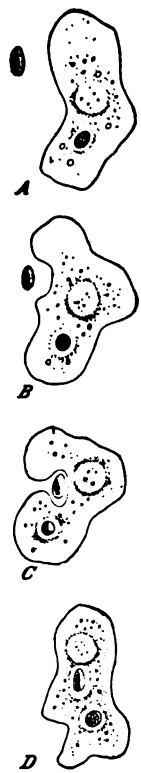

FIG. 3.—The amœba taking food (as seen under a high power of the microscope).

One-celled animals. — The cells of the body, owing to the fact that they have a wall, soft contents, and a nucleus, resemble minute one-celled animals sometimes found in stagnant water. Figure 3 shows the appearance under the microscope of the amœba, one of these small animals. The amœba seems to be hardly more than a minute drop of jelly, yet it lives and does in a simple way many of the things

that the human body can do. It moves by pushing out a part of its body; it takes in food by rolling a process of its body around the food to be eaten; and after digesting the part it wants, it discards the indigestible portion of the food. If the amœba is struck or jarred, it reacts by moving its body. It absorbs oxygen * from the air and it gives off carbon dioxide.* When it attains a certain size, it divides into two parts. It does not divide, however, and produce new individuals until it has reached its full growth.*

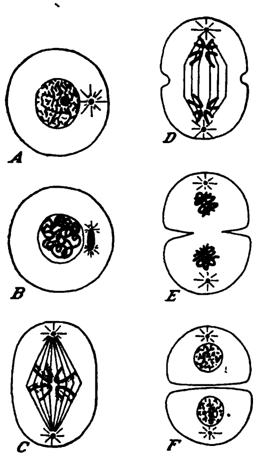

FIG. 4. — A cell undergoing division. *A*, cell before division; *B*, thread-like formation of the vital parts of the nucleus; *C*, equal division of the nuclear thread; *D*, separation of the nuclear structure for the new cells and commencing constriction of cell body; *E*, nuclei beginning return to resting states; *F*, complete division of cell body into daughter cells whose nuclei have returned to the resting states.

The origin of cells. — For many years it was believed that life originated spontaneously. This view is called the theory of spontaneous generation. We know now, however, that all cells are derived from cells (Fig. 4) and that the vast number of different cells which compose a living body are all derived from two single cells, the *ovum* * (Fig. 5) and the *spermatozoön.** The health and strength of these two cells are dependent upon the health, strength, and vigor of the whole body. In this respect, the strength and vigor of the race are dependent upon the strength and vigor of each member of the race. This is an important responsibility because each person, by being strong and vigorous, makes it possible for coming generations to have health and strength. In this way, health is a duty that no one may neglect.

The properties of cells. — If we say that a stone is hard, that it sinks when thrown into the water, that it will break

when hit with sufficient force, we are speaking of the properties * that belong to the stone. Cells also have properties —

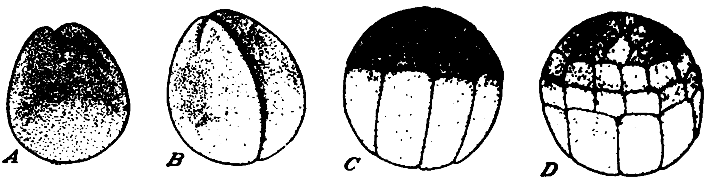

FIG. 5. — Different stages in the development of the frog's egg (*A*) to form the body of the frog. In *D* the egg (ovum) has divided many times, and presently these cells will begin to change into bone, nerve, and muscle cells, and other types of body cells.

the characteristics which distinguish them from other structures.

In the first stages of the formation of the body, the cells which later on develop into muscle cells, or nerve cells, or skin cells, look very much alike and have identical properties. They can divide and reproduce themselves (the property of *reproduction* *) ; they can take up food and build it into tissue * and remove the waste (the property of *metabolism* *) ; they can receive an impulse and conduct it to all parts of the cell (the property of *irritability* * and *conductivity* *) ; they can respond to a stimulus and contract the cell body (the property of *contractility* *).

They also change in their properties. Certain cells become unable to contract, but are very proficient in sending nerve impulses; others cannot secrete digestive juices, but they are able to reproduce the individual. We say, therefore, that the sex cells develop the property of reproduction, the nerve cells the properties of irritability and conductivity; the digestive and excretory cells develop the property of metabolism, and the muscle cells the property of contractility.

Tissues formed from cell groups. — Cells of one kind group themselves together to perform a particular function and are called a *tissue*. We speak of muscle tissue, and we

understand that there is this grouping of many muscle cells for the purpose of contraction. Therefore, a group of cells of a particular kind to perform a particular function is known as a *tissue* (Figs. 6, 7, 8).

Organs formed from tissues. — Tissues combine to perform more effectively a highly complex act. The resulting structure is an organ. Tissues grouped in a definite way to coöperate their tissue functions in some special task are known as an *organ*. The stomach, for example, is an organ composed of muscle, nerve, and connective tissues, and each tissue coöperates in the digestion of food in the stomach. The muscle contracts the stomach and moves the food at the proper time into the intestine; the nerve tissue tells the muscles when to contract, and the epithelial cells when to secrete digestive juice; and the connective tissue binds the other tissues together to produce the whole organ.

Similarity between living organisms and social groups. — It has been learned that the body is composed of cells with special properties grouped into tissues; that the tissues are arranged to form organs. An individual constructed to carry on the activity of life by means of parts or organs which are separate and yet dependent upon each other is called an *organism*.* Man is, therefore, frequently referred to as an organism. The term is sometimes used with reference to society. The relation of the parts of the body to the whole body and of the individual man to the organism of society is very important. We have learned that there are organisms composed of only one cell and that such organisms may show all the properties of living matter. As soon as an organism becomes multicellular,* an arrangement is necessary for groups of cells to take up certain special tasks. This arrangement and organization permits greater achievement in the group because certain cells are free to accomplish results which would have been impossible in an unicellular* type of organism.

This division of labor among cells may be likened to a similar division of labor that occurs in human society. A city with its million inhabitants is a superior social group for the performing of greater tasks than are possible for the people in a pioneer settlement. In this respect, the organism, man, is superior to the amœba. Both man and a city are superior as types because they have greater opportunities and can make better use of abilities in acts that enrich the life of the world. The city is more complex, more alive, more sensitive than the pioneer settlement, but in order to maintain this highly specialized state it must be exceedingly watchful against disease * and degeneration.* In this same way, man, a highly specialized organism, superior to the unicellular animals, needs to be careful of the laws of life and health, the observance of which makes such high specialization * possible. In each case then, in animal life and in human society, specialization produces a superior life, but it also produces the need for intelligent care of the basis of life. The castle needs a better foundation than the kennel.

One-celled animals and primitive society. — The basis of life for the complex organism is the same as that for the simple organism. The amœba in its self-dependence is like the savage living alone. Modern man with his highly developed body is like the organization of a great city. In each case, however, the simple organism and the complex organism resemble each other by requiring food, air, and water, by needing activity of the proper kind and the removal of body waste. In a complex society, it is necessary that all groups of men do their special tasks well. In a similar fashion, man must look for his strength and security to the proper functioning of all his cells, and in no instance may he with impunity sacrifice the removal of waste to the development of the nerve cell. All must be cared for.

The developed body and modern society. — The more complex an organism becomes the greater is the necessity for

coöperation. In human groups there is this important relation between men and women and their fellow members in society, which illustrates the coöperation required in the developed body. Members of the human family are dependent upon each other. The chemist has to rely upon the integrity of the manufacturer of chemical apparatus; the farmer is dependent upon the chemist for a complete and accurate analysis of his soil; the child in school is dependent upon the teacher for guidance and instruction; and every man must rely upon other men to do their work honestly and efficiently. Therefore, just as man is dependent upon his fellow men, just as eight players on a baseball team are dependent upon how the ninth player plays the game, just as the work of a class is dependent upon the coöperation of the individual members, so in the body, cells in one place are dependent upon the action of other cells forming some other part of the body and doing a different sort of work. The muscle cells cannot act unless the nerve cells do the work of sending nerve impulses; the nerve cells cannot send and receive impulses unless the heart and lung cells do the work that is expected of them. This interdependence of cells upon other cells and of men upon other men is very important.

Similarity between the human body and a city. — In comparing the city with an animal such as man, it will be noted that the construction of the city and the way its work is carried on resemble the body and the activities of its cells. The city proper is composed of buildings that serve definite purposes; the body is made up of a great number of distinct cells which perform special tasks. The stores on the outskirts of the city obtain their supplies from the wholesale district by the established channels of trade and commerce; the body cells receive their nutritive supply through the blood channels which run past the great digestive tract and respiratory tract. The blood with its millions of red blood cells transporting life-giving oxygen, and with its plasma,

carrying life-giving food, resembles a continuous chain of auto trucks transporting the necessities of life to the outlying population. The waste products are carried by the blood to the kidneys, skin, and lungs — organs which serve to remove this waste material. So in a city the " white wings " gather the ashes, rubbish, and garbage and, carrying it to the disposal plant or scows in the river, perform for the city the function of excretion.

The city is controlled and directed by officers elected by the people. These officers must provide for the life and development * of the people, not only with reference to what they need in the way of food, protection, and recreation, but also with reference to what other cities are doing in providing for man the best opportunities for life. In similar fashion, the body is controlled and directed by the nervous system, which constantly receives messages from all the cells of the body. To these messages it responds and provides the necessities of life. It also responds to messages from other men. In this way, man and city, both, in cooperation with other groups and led by high ideals, achieve the best development.

GLOSSARY

Carbon Dioxide. — A gas having the composition of two molecules of oxygen in combination with one of carbon. It is heavy, colorless, and incombustible. It is produced in the decay of animal and vegetable matter and in the bodies of animals during activity.

Conductivity. — Ability to carry heat or electricity. In nerves, it is the ability to transmit stimuli from one part of the body to another.

Contractility. — Power to change the shape, to shorten, in the case of a muscle. In single cells, the shortening in one direction produces an increase in diameter in the opposite direction.

Degeneration. — The change in the chemical constitution of the cells from a complex to a simpler chemical form.

Development. — A series of changes by which the body progresses from a lower to a higher type of being. Growth may best be thought of as an increase in substance; development refers to the organization of that substance.

Disease. — The general term for any deviation from health. It may be caused by destruction of essential body cells, or by poisoning so that the cells are unable to function properly.

Globule. — A small spherical structure.

Growth. — The process of increasing in size. It is to be distinguished from development, which refers to organization of the mass.

Irritability. — The responsiveness that living matter shows to more or less rapid changes in external conditions, manifested by motion, change of form, and in other ways.

Metabolism. — The act or process by which on the one hand food is built up into living material, and by which on the other hand the living matter in protoplasm is broken down into simple, waste elements for removal from the body. Sometimes the building up of food into protoplasm is called anabolism; the breaking down into simple waste products, katabolism.

Multicellular. — Many-celled.

Nucleolus. — A small, well-defined particle found within the nucleus of the cell. It is easily stained with staining fluids, and because it absorbs stain more readily than the nucleus, it is distinguished without difficulty.

Nucleus. — A round or oval body within the protoplasm; it is surrounded by a delicate membrane. The nucleus is responsible for the vital functions of the cell.

Organism. — A body composed of different organs or parts, performing functions that are mutually dependent and essential to life. A single cell may be considered an organism although the different parts are not readily distinguished.

Ovum. — A cell produced by the generative organs, the ovaries, of the female. It is capable of producing a new individual.

Oxygen. — In chemical terms, oxygen is represented by the letter O. It is a colorless, tasteless, odorless gas, very abundant in nature. It was first discovered by Priestley in England. It combines with other chemical elements, and all mechanical power obtained from combustion, whether through the medium of steam, electricity, or muscular action, depends upon oxidation.

Properties. — Distinguishing characteristics. Qualities that make the object what it is.

Protoplasm. — The semiliquid, more or less granular substance that forms the principal portion of an animal or vegetable cell. It is present in all organized bodies and so Huxley called it " the physical basis of life."

Reproduction. — The process by which an animal or plant gives rise to another of its own kind and therefore the process by which life is continued from one generation to another.

Specialization. — The setting apart of an organ or part for performing a particular function.

Spermatozoön. — The germ-cell of the male which joins with the ovum in reproducing a new individual. These cells are composed of protoplasm and illustrate specialization.

Tissue. — An arrangement of cells in a definite manner. The cells are grouped in masses of one kind.

Unicellular. — One-celled. Consisting of a single cell.

CHAPTER II

TISSUES

I. Kinds of Tissues.
II. Epithelial Tissues.
  Mucous and serous membranes
  Glands
  The teeth
  The skin
  The hair
  The nails
III. Indications of Good Health.

Kinds of tissues. — In all but the single-cell type of life the body is composed of an arrangement of many cells. These cells, as we have learned, are of different kinds. They have come from a single cell but in developing they have specialized in order to do a certain kind of work. From the cells there has developed a substance which lies outside the cell wall; it is known as the intercellular substance.

Now, it is a very important fact that certain tissues are more highly specialized than others. Such tissues become more highly developed because they have a more important work to do. It is generally understood that nerve tissue is more valuable than the tissue that forms our nails or our hair. Nevertheless, some foolish people take better care of their hands than they do of their nervous system. Physiology should teach us what is relatively more important.

In the construction of the body different types of tissues are used. By analogy, the body may be likened to a house, where sills, rafters, plates, and studding are used for the

frame. Other material different in shape and form is used to fashion the separate rooms, to provide a covering, and to make the place habitable. So the tissues in the body serve particular purposes. We say, therefore, that the muscle and the nerve tissues serve the body in acting and thinking; the epithelial and the connective tissues afford protection and support to the muscle and the nerve tissues. Of these four tissues, the epithelial and the connective may be regarded as elementary, being common to both plants and animals. Muscles and nerve tissues are seen only in animals. The four kinds of tissues, therefore, are *epithelial*, *connective*, *muscular*, and *nervous*.

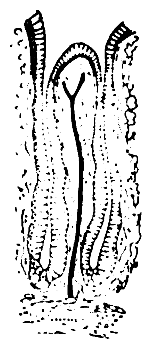

Fig. 6. — Two gastric glands. Simple tubular glands such as these may be likened to a well; the cells are like the bricks of the well-curb.

Epithelial tissues. — Covering the surface, and lining every cavity and tube of the body is a tissue consisting of one or more layers of distinct cells, forming what is called epithelial tissue. It is very simple, consisting merely of cells packed closely together, and united by a very small amount of cement substance (something like the white of egg), which holds the cells together. The cells may be in a single layer or in many layers. No blood vessels pass into the epithelial tissue; the cells derive their nourishment * from the blood exuded into the adjacent tissues.

The epithelial tissues may be placed, according to their function, in two divisions. One is chiefly protective in character, such as the skin, the lining of the mouth, trachea, and alimentary tract. The other kind of epithelial structure consists of cells that contain highly active protoplasm. These cells are engaged in forming secretions* from food brought to them by the blood. Such are the cells of the salivary glands, which secrete the saliva *; of the gastric glands, which secrete gastric juice*; of the pancreas, sweat glands, kidneys,* liver,

etc. This class of epithelial tissue is of the greatest value in removing waste from the body and in preparing the food for use by the body.

*Mucous and serous membranes.** — Epithelial cells, in secretory glands, within the body produce powerful digestive juices, as in the liver, stomach (Fig. 6), pancreas; or they serve to protect passageways and cavities (Fig. 7) with a secretion whose function is chiefly to lubricate the part. All cavities * to which air has access, as the mouth, stomach, and lungs, are lined with one or more layers of closely packed epithelial cells, called *mucous membrane* (Figs. 7, 8). All cavities from which the air is cut off, as the heart, are called serous cavities, and have a lining of epithelial cells forming what is called a *serous membrane.*

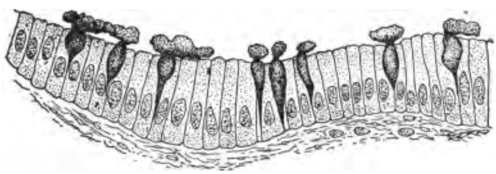

FIG. 7. — Cells forming a membrane. (Mucous membrane of intestines.) A few cells (dark) that secrete mucus are shown.

These membranes secrete a lubricating fluid. The fluid formed by the mucous membrane is called mucus; that formed by the serous membranes is called serum. The line where the skin and the mucous membrane of the lips join can be plainly seen, as the latter membrane is so thin that the color of the blood shows through it.

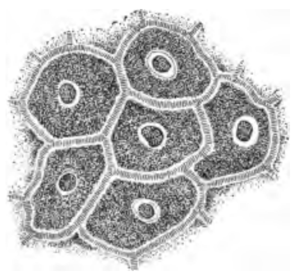

FIG. 8. — Epithelial cells lining the mouth.

Glands. — Glands (Figs. 9–13) are always lined with epithelial cells, which form a secretion. These glands vary in shape; some being tubular, others bag-shaped. The cells of the gland, in their own distinctive way, make use of the

various chemical substances in the blood, so that one gland secretes oil, another perspiration,* another saliva, another gastric juice, etc. The kidneys are important glands which resemble some of the glands of the skin in that they secrete injurious substances that must be removed from the system. Secretion is the name given the various fluids formed by glands. If this fluid is waste to be removed, it is called an excretion.*

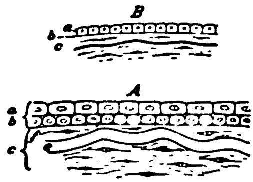

FIG. 9. — *A*, typical structure of a mucous membrane with two layers of epithelial cells, *a*, *b*, *c*, the connective tissue beneath, with *e*, blood-vessels; and *f*, connective tissue cells. *B*, the same with one layer of cells resting on *b*, the so-called basement membrane.

Secretion by glands is not simply a process of soaking or sifting through. The cells of these glands are wonderful little chemical laboratories and they produce the different secretions from the blood in their own way. Moreover, by the aid of the secretory nerves, they can for a time regulate the amount of secretion regardless of the quantity of blood circulating around them, although usually the amount of secretion is greatly influenced by the supply of blood in the skin (Chap. XII). Sometimes the skin is hot from the abundance of blood flowing through it, as during a fever, but it is dry then, as well as hot, because the sweat glands are not active. At times, under the influence of excitement or fear, a person breaks out in a profuse perspiration, which is cold, however, for there is little blood in the skin.

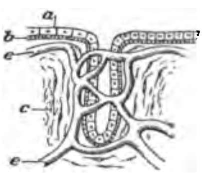

FIG. 10. — A simple tubular gland with blood-vessel. The letters, *a*, *b*, *c*, and *e* refer to the same structures as shown in Fig. 9.

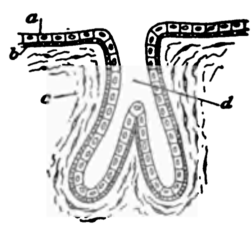

FIG. 11. — A tubular gland dividing. *d*, duct of the gland. Name *a*, *b*, and *c*.

The teeth. — The teeth are developed from the same kind of tissue (epiblastic*) that produces mucous membrane, glands, and skin. These structures, like the hair and nails, arise from papillæ* in the dermis of the skin. A tooth growing from epithelial-forming cells extends down in a depression in the jawbone, called a socket,* and is held in place largely by the tightness with which the root, or lower part, fits into the socket. The visible part of the tooth is called the crown.

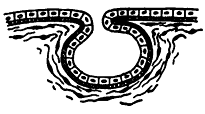

Fig. 12. — A sac-like gland.

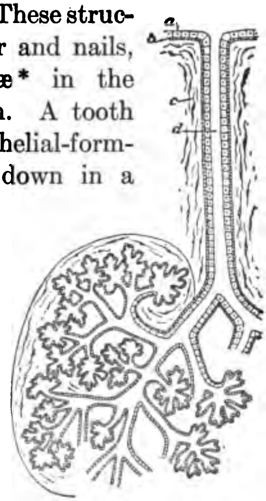

Fig. 13. — A racemose or branching gland, part only being shown. Name the parts indicated by *a*, *b*, *c*, and *d*.

Permanent Teeth. — A complete set of teeth in adults consists of sixteen in each jaw or thirty-two in all. They are named according to their form and the uses to which they are adapted. There are eight (Fig. 14) in each quarter of the mouth; and if the names of the eight in one quarter are learned, you know the names of the thirty-two, since they are designated by the same names, in the same order, in each quarter of the mouth. Looking then at the teeth in one half of one jaw and naming them in order from front to back, there are two *incisors*, one *canine*, two *bicuspids*, and three *molars*. How many of each kind are found in the whole mouth (Fig. 14)?

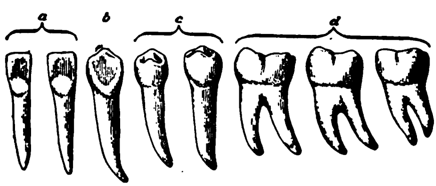

Fig. 14. — Teeth from one side of the lower jaw of man. *a*, incisors; *b*, canine; *c*, bicuspids; *d*, molars.

The eight teeth in front are for the cutting of the food, and hence are called incisors, or cutters. They have chisel-like edges. Do the edges of the upper and lower teeth usually meet in the mouth, or do they miss each other like the blades of scissors? The incisors are very long in gnawing animals such as rats and squirrels. Next to the two incisors in each quarter of the jaws, comes one canine, so called because the corresponding tooth in the jaws of dogs is well developed. In cats, tigers, dogs, and other flesh-eating animals, it is suited for tearing. It has only one root, but that is a long one. The two upper canines are fancifully called the "eye teeth," and the two lower, the "stomach teeth." Next in order behind the canines are the two bicuspids, which are grinding teeth. Their crowns are broad. Last of all come the three large grinders, called molars. Are the grinding surfaces of the molars smooth or rough? Are they like or unlike the surfaces of the bicuspids? The last molar in each jaw is called the wisdom tooth, because it does not come until the person is supposed to have reached years of discretion. Activity is the law of life, and the wisdom teeth are so far back in the mouth that they are not much used; therefore, they do not usually remain so long as the others.

Milk Teeth. — Milk teeth are the first teeth to appear. The teeth just described are those of the permanent set. The first or temporary set of teeth — also called the milk teeth — consists of teeth the same in name and number as those of the permanent set except that the three large molars in each half of the jaw, twelve in all, are lacking; so there are twenty teeth in the temporary set (Fig. 15). The milk teeth come in the first two years of life, and begin in the sixth or seventh year to be pushed out and replaced by the permanent set. They are all gone by the twelfth year. On the other hand, the presence of the milk teeth is important in the development of the jaw. If a milk tooth remains so

long as to cause the tooth of the second set to grow out of place, the first tooth should be removed. If the milk tooth decays, it should be filled, and if the filling comes out it should be replaced by the dentist; the milk teeth are an important

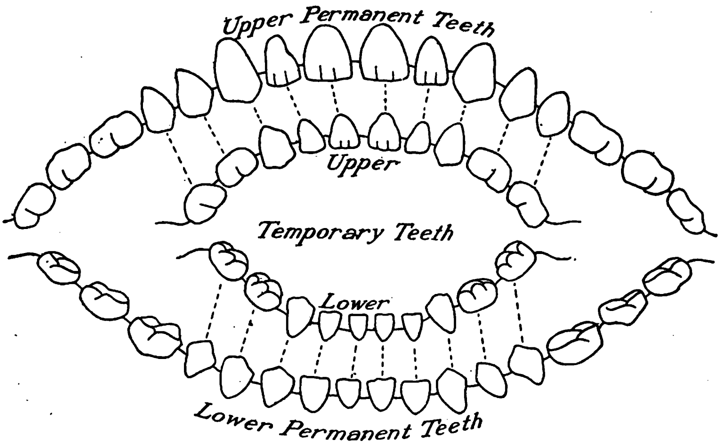

FIG. 15. — Diagram of temporary and permanent teeth, showing only the parts outside the gum line.

stimulant for the proper development of the permanent teeth, the jaws, and the bones of the face.

Parts of a Tooth. — The main part of the body of a tooth is dentine* (Fig. 16). The dentine of the teeth of elephants and other large animals is the ivory of commerce. It is commonly used to make piano keys, fans, and many novelties. In the central part of the dentine is a space called the pulp* cavity. The soft substance, called the pulp, contains the nerves and blood vessels, which enter at the tip of the root. In the socket, the dentine is covered by cement; above the socket it is covered by enamel, a substance harder, denser, and more shining than the dentine.

The enamel wears off of the top of the crown between the twentieth and thirtieth years. Although the dentine

is exposed through the wearing or breaking of the enamel, it will last for years without decaying, but it is more likely to decay than the enamel. We should never run the risk of breaking the enamel by crushing hard candies or cracking nuts. A tooth should never be pulled if it can be saved by being filled; for pulling a tooth means not only the loss of one tooth, but the end of the usefulness of the tooth opposite to it, and imperfect chewing in that part of the mouth. Losing a tooth is equivalent to losing a part of life.

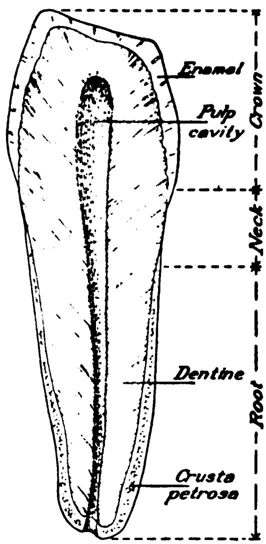

FIG. 16. — Vertical section of a bicuspid tooth, magnified.

Hygiene of the Teeth. — Decay of the teeth is caused (1) by using only soft food which requires no pressure of the teeth while chewing it; (2) by particles of food that lodge between the teeth and become quickly decomposed* in the warm, moist mouth; (3) by the collection of tartar on the teeth. This is a yellowish deposit that forms on the teeth when they are not kept clean. (4) Constant nibbling of candy causes injury to the teeth through the fermentation of the sugar left in the mouth.

In cleaning the teeth, the toothbrush should be rubbed up and down as well as across the teeth. Most tooth powders are made from chalk as a base; and fine precipitated chalk* is considered perfectly satisfactory for cleansing the teeth. The teeth should be cleansed at least twice a day and always before going to bed at night. The teeth should be examined once a year by a dentist, and the cavities promptly filled. Adenoids* should not be allowed to deform the jaw and so

produce crooked teeth (Fig. 17). It may be necessary to have adenoids and tonsils removed.

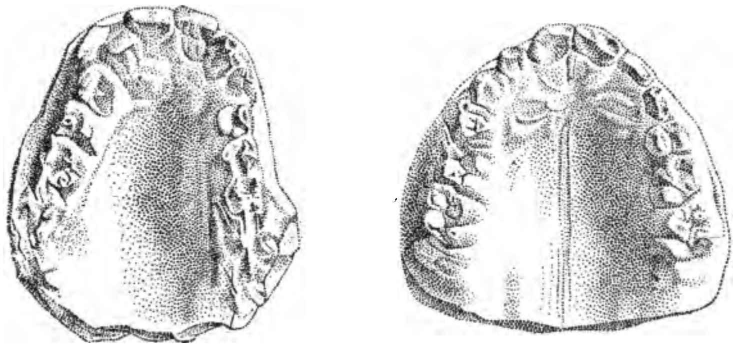

FIG. 17. — Casts of the upper jaw of two children twelve years old. The left one shows typical narrowing of the arch, overlapping of the teeth, and elevation of the palate due to adenoids. The right one is that of the jaw of a healthy, well-built child. (Drawn from photograph by Dr. Frank Mathews.)

The Department of Health of the City of New York, in an effort to help the children in the schools to have better teeth, has issued the following instructions to parents:

DEPARTMENT OF HEALTH

THE CITY OF NEW YORK

Instructions to Parents Regarding the Care of the Mouth and Teeth

The physical examination of school children shows that in many instances the teeth are in a decayed and unhealthy condition.

Decayed teeth cause an unclean mouth. Toothache and disease of the gums may result.

Neglect of the first teeth is a frequent cause of decay of the second teeth.

If a child has decayed teeth, it cannot properly chew its food. Improperly chewed food and unclean mouth cause bad digestion, and consequently poor general health.

If a child is not in good health, it cannot keep up with its studies

in school. It is more likely to contract any contagious disease, and it has not the proper chance to grow into a robust, healthy adult.

If the child's teeth are decayed, it should be taken to a dentist at once

The teeth should be brushed after each meal, using a tooth brush and tooth powder.

The following tooth powder is recommended:

2 oz. powdered precipitated chalk.
½ oz. powdered castile soap.*
1 dram powdered orris root.*
Thoroughly mix.

This prescription can be filled by any druggist at a cost not to exceed fifteen cents.

The child should take the tooth brush and powder to the school and receive instructions from the nurse as to their proper use.

Issued by Order of the Board of Health

The skin. — We have learned that epithelial cells form mucous and serous membranes, teeth, and secreting glands. They also form the skin covering the body, and from these skin cells there develop the hair and the nails. The thickness of the skin is due to the great number of cells composing it. These cells are arranged in a definite manner, in two layers, the dermis and epidermis.

The outer layer, or epidermis, rests on the inner layer, the dermis (Fig. 18). The dermis is called the true skin. The epidermis is composed of a mass of cells held together by a cement substance. Those near the surface are hard and flattened; those deeper down, near the dermis, are round and soft. The lowest layers contain a pigment* consisting of minute grains of coloring matter. The varying amount of this pigment present causes the difference in hue of the blonde and brunette and the light and dark races. Freckles are due to an increase of pigment in patches of neighboring cells. Some persons lack the pigment entirely; their hair and skin are white, the eyes pink. They are called albinos.

The Dermis. — The main part of the skin is the dermis; it is chiefly a network of fibers. This is the part of the skin of animals that is tanned for leather. Did you ever notice the fibrous appearance in the leather of a shoe that has become much worn? Which side of leather is smooth, the side covered by epidermis, or the other side? The dermis is connected with the body beneath by a loose tissue consisting of fibers interwoven with cells of fat (Fig. 18). This tissue, together with the skin itself, partly conceals the outlines of the muscles beneath. Yet artists study the muscles carefully, as their shape shows faintly through the skin and gives a key to the human figure.

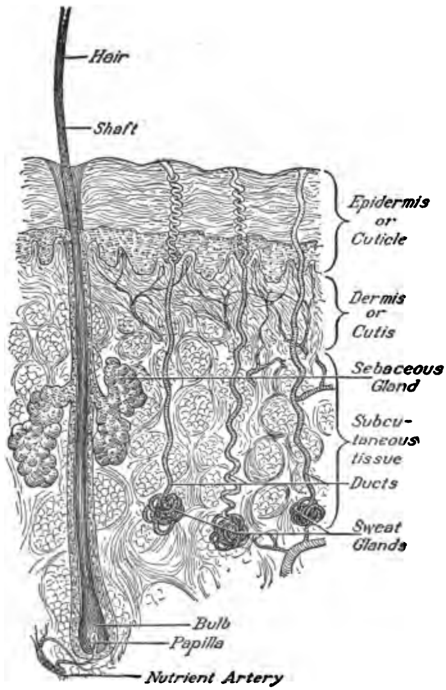

FIG. 18. — Sectional view of the skin, magnified. Find: oil (sebaceous) gland, sweat gland, sweat duct, hair bulb. Compare thickness of epidermis, dermis, and subcutaneous tissue.

The outer surface of the dermis grows into numerous little projections called papillæ. If its covering of epidermis were taken off, the dermis would appear somewhat like coarse velvet because of its unevenness; for the prominences or papillæ appear, in a cross section of the skin, under the microscope, buried beneath the cells of the epidermis, like

a tiny mountain range. As the epidermis fills up the valleys between them, the papillæ do not show plainly on the surface of the skin. However, on the palm of the hand and fingers, where the papillæ are especially numerous, they are

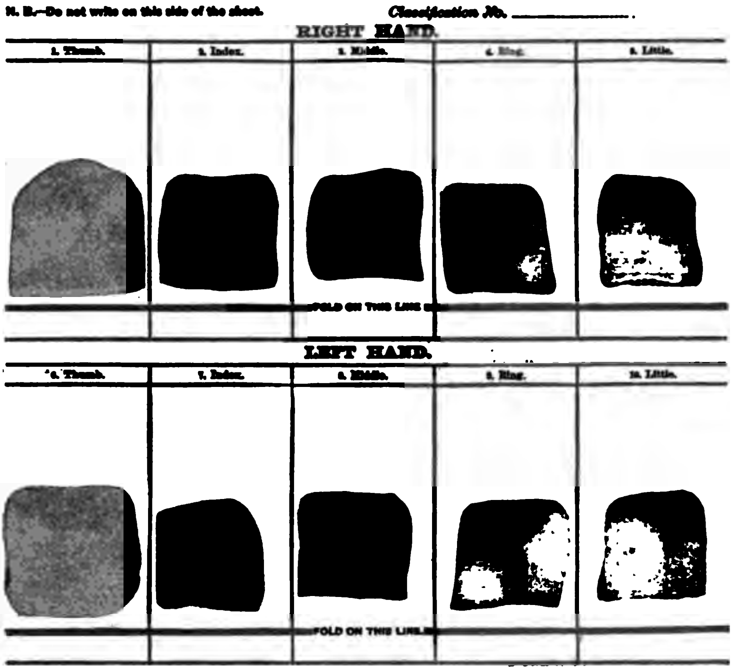

Fig. 19. — The finger prints of the right and left hand. The marking is distinctive for each individual.

crowded into rows, their positions being shown by the parallel ridges seen on the epidermis of the palm. These markings are very distinct on the palm. Moisten the index finger and notice that an imprint of the finger shows when pressure is made on white paper (Fig. 19). Under what conditions are finger prints of service? Within the papillæ are found the ends of nerves and loops of small blood vessels called capillaries* (Fig. 18).

Epidermis. — The cells of the epidermis which lie next to the dermis are living cells. They are kept alive by nourishment brought by the liquid portion of the blood in the blood vessels of the neighboring papillæ. These cells grow and when they have matured they divide and produce new cells. The multiplication of the cells would cause the epidermis to increase greatly in thickness, were not the outer cells constantly worn away by friction. This happens the more easily because the outer cells are dead cells. The new cells forming beneath push them so far away from the dermis, that nourishment from the blood no longer reaches them, and they die.

By this constant loss and renewal, the body always has a comparatively new outer skin. Even on the scalp, which is partly protected from friction, the flat dry cells are constantly coming off. If there is much oil on the scalp, the cells stick together and form flakes called dandruff. This physiological shedding of the cells of the epidermis is to be aided by bathing the skin and shampooing and brushing the hair.

Organs of the Skin and Their Functions. — Lodged among the fibers of the dermis and supported by them are (1) a fine network of blood vessels; (2) a fine network of nerves; (3) several million sweat glands; (4) a great number of oil glands. Suppose you were to stick a pin into the dermis. The pin would first pass through the epidermis. After entering the dermis there would be two signs that certain structures had been encountered. What are these structures? What signs would appear?

The *blood vessels* in the skin are fine tubes which carry the blood supply to and from the skin. These vessels have muscles in their walls, and when stimulated through the nerves of the skin, the vessels change their size. Warmth causes an increase in size of the vessel and more blood is brought to the skin; cold causes a decrease in size and the opposite effect is produced.

The *nerves of the skin* serve two main functions. One function is to control the size of the vessels by responding to changes in temperature; the other is to make us aware of the character of things we touch. The nerves of the skin of the fingers in this latter function are more sensitive* than those in any other part of the body.

The *sweat glands*, or perspiratory glands are little tubes, lined with epithelial cells, which pass through the epidermis and down into the dermis. The tube is coiled

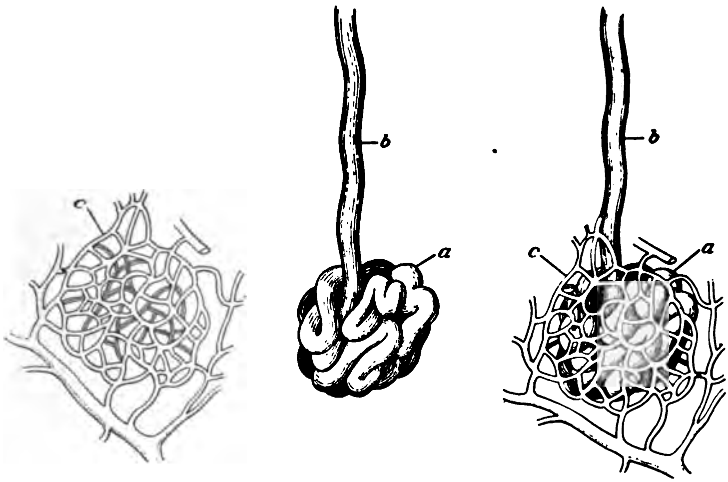

Fig. 20. — Coiled end of a sweat gland, epidermis not shown. *a*, the coil; *b*, the duct; *c*, network of capillaries. The gland and capillary network are shown separated and combined to indicate how completely the organ is supplied with blood.

into a ball in the true skin, where it is surrounded by a network of capillaries (Fig. 20). Its course through the epidermis is spiral like the turns of a corkscrew. Its opening on the surface is called a pore. The coiled part is supplied with nerves which stimulate the cells to secrete perspiration. The cells obtain their supply of material from the blood, and this supply is controlled by the

nerves which regulate the size of the arteries* leading to the skin.

The sweat glands take up water and various other substances from the blood and pour them out on the surface of the epidermis. The water evaporates, but the salt and other solids in the perspiration are deposited on the skin. Usually the amount of perspiration from each gland is so small that it evaporates as soon as it reaches the surface, and hence does not become visible. On this account it is called insensible perspiration; it becomes sensible perspiration when it is formed rapidly in warm weather or during vigorous exercise. It does not evaporate so quickly in a moist atmosphere; and those who live near the seacoast or in rainy regions show more perspiration than those who live in dry regions. The evaporation of this moisture on the skin cools the body. Why is the heat so oppressive on a "muggy" day? The amount of perspiration averages about one and one half pints a day. Is the skin more active in throwing off impurities in winter, or in summer?

The *oil glands*, or sebaceous glands, are small, irregularly-shaped cavities which open into the little pits from which the hairs grow (Fig. 18). A few oil glands open directly upon the surface. They are lined with epithelial cells. The cells deposit a kind of oil, which flows out of the mouth of the glands, renders the epidermis flexible and less penetrable by water, and prevents it drying out by evaporation and cracking open. It is also the natural "hair oil," for softening the hair and keeping it from becoming brittle. The oil glands of the center of the face are especially large and numerous. When their mouths are stopped by dirt, they become distended with oily material and cause blackheads. Oil glands are absent from the soles and palms.

Protection of the Skin. — Clothing does not give heat to the body but helps to prevent the escape of bodily heat. Linen and cotton absorb moisture readily and allow it to

evaporate rapidly. They thus serve, when worn next to the skin, to keep the body dry; the evaporation, however, if very rapid may chill the body. Woolen absorbs moisture quickly, but parts with it slowly, and, in the case of those who perspire freely, the damp clothing next the skin may conduct away the heat. In this way woolen may seem cool. But dry woolen contains much air in the meshes of the cloth; and as this is a non-conductor of heat, such clothing is the warmest of all, silk ranking next. In cold climates woolen should be worn next to the skin, and should not be laid aside until the heat of summer begins. In warm climates, like that of the Gulf States, it should not be worn next to the skin at all, even in winter, except by the very delicate, and it is a question as to whether woolen does not do more harm than good, even to the delicate, as it relaxes and weakens the skin. If it is worn in such climates, with the warmth of spring it should be changed for less relaxing fabrics. White clothing reflects the heat of the sun; dark clothing absorbs the sun's heat. Rubber clothing prevents moisture from

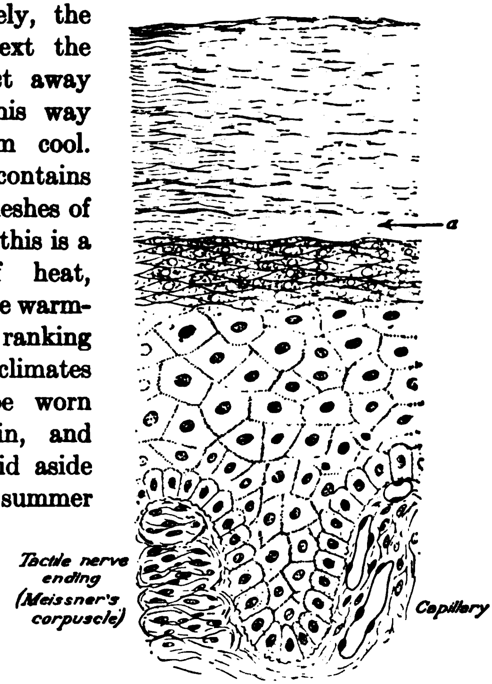

FIG. 21.—*a*, arrow indicates where the epidermis separates in the formation of a blister. The serum of the blister exudes from the cells below, which are supplied by capillaries.

penetrating to the body and also prevents perspiration from escaping. Bed clothing should not be too heavy. On account of the warm air between them, two coverings are warmer than one equal to the two in thickness. The bed clothing should be aired thoroughly every morning.

When the epidermis is broken so that the true skin is exposed, the epithelium* at the edge of the break usually produces new cells to cover and heal the opening. But if new cells do not form, sufficient to bridge the opening, the dermis sprouts through, forming proud flesh, which must be scraped off or cauterized before the epidermis can complete the healing. In the case of a blister, the lowest cells of the epidermis are not removed (Fig. 21), hence the epidermis is readily renewed. Preparations advertised to make new skin over a cut or injury should not be used. Nature will grow the epidermis if the part is kept clean.

When the epidermis is weak the papillæ over a small area sometimes become overgrown, so that they project above the skin, and form a wart. If it is burned away with acid, the epidermis will grow over the place. Why is a wart rough? How does it differ from a mole? Which is more likely to increase in size? Which has more pigment? Which contains hairs?

Hygiene of the Skin. — The scales of the epidermis are gradually passed off, and with the secretions from the oil glands and surface dirt, they tend to form a pellicle* or coat which interferes with the proper functioning of the oil and perspiratory glands. Bathing removes this pellicle and is of great importance in maintaining a healthy skin. The cold bath is intended to stimulate the body; the warm bath is cleansing. The best time to take the cold bath is before breakfast. If this practice is started in the summer, it may be continued through the winter and not be disagreeable even with very cold water. It is best to have a warm room for the bath. Every one may take a cold bath because a sponge

and a basin of water are the only necessary articles, although a shower is to be preferred. A warm bath is more suitable on retiring than on rising; it is also more suitable for a person who is fatigued. A warm bath has a soothing effect on the nervous system. The proper time to bathe is just before a meal or at least three hours after. Sea-bathing is beneficial to the health of the skin and body in general, but its effects are due to the enjoyable exercise and pure outdoor air of the seashore. Bathing in ocean or lake should not be prolonged until the bather's lips are blue.

The complexion is the outward expression of inner health. A good complexion cannot be bought in a box or bottle. An artificial complexion produced with cosmetics and face powder is as barbaric and unnatural as the war-paint of the savage. Do you know a girl who paints and powders her face? Is she a wholesome, healthy appearing girl? A little powder is of value at times on oily skins, but its abuse gives an improper appearance and interferes with the proper action of the skin.

The face should be washed at least twice daily. Cold water should be used because it improves the circulation, it tones up the elastic fibers, and it prevents chapping and roughening of the skin. Unless the face is very dirty it should be washed without soap. A vigorous washing with cold water or with warm water followed by cold water will remove the dirt in most cases. If the skin is dry a cream may be used to soften it, but it is to be remembered that the best way to get a beautiful complexion is to take proper care of the functions of the body and to indulge in regular exercise, preferably out of doors.

The Skin as an Index of Health. — People prefer a clear skin of fine texture to a mottled, pimply, coarse skin. This preference is based partly on the attractiveness of the one and the repulsiveness of the other. It is also sustained by the wholesome desire to appear well and strong, for it is

recognized that the skin very delicately and accurately shows the bodily condition.

In an effort to state clearly from your own observation the value of health, answer the following questions:

1. Name five blessings in youth or in later life that result from good health.
2. Name five unfortunate results of bad health.
3. Name five things that people apparently value more highly than health.
4. Think of ten grown persons. How many of the ten are in sound health so far as you can tell? What are the signs?

The hair. — It has been learned that the papillæ in the dermis are composed of epithelial cells arranged in minute projections. A hair is composed of a column of minute epithelial cells which grow from a depression in a papilla. This depression is the hair follicle* or "root." Therefore, a hair grows from a papilla below the epidermis. The only point at which the cells of the hair and, therefore, the hair itself, are living and growing is at the top of the papilla, deep down in the follicle (Fig. 18). From this it is easy to see that the common notion that cutting off the ends of the hair, either by shaving or trimming with scissors, causes it to grow faster and stronger, is erroneous. It may stop the splitting of hairs and thus prevent the wearing away of the hair. Of course, when the hair or beard is short its growth is more noticeable. Long hair seems by its weight to give exercise to minute muscles in the skin and to strengthen the flow of blood, thus adding to the vigor of the hair. The cut end of a hair is nearly round in the straight-haired races, as Indians and Chinese;

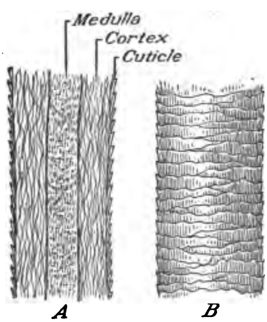

FIG. 22. — *A*, section of hair; *B*, piece of human hair, magnified.

it is oval in the wavy-haired white race, and flattened still more in the kinky-haired negro race.

Hair is very durable (Fig. 22); that found on Egyptian mummies has remained unchanged through several thousand years. It is elastic and is said to stretch one third of its length without breaking. Hair absorbs moisture readily and for a time its length is considerably increased thereby. Each hair follicle has fine muscles connected with it. Cold or fear may cause the muscles to contract and the hairs, which are usually in a slanting position, to stand erect. This causes the hair to afford a better protection to the animal from cold or blows. "Goose skin," which occurs if a cold bath is unduly prolonged, is caused in the same way; but the hair on the human skin is so fine that the goose skin avails little against cold.

Superfluous hairs sometimes grow on unusual parts of the face. To remove this hair so that it will not grow again, the papillæ at the bottom of the follicles must be destroyed. This is no easy matter. Numerous "infallible remedies" are advertised, but the only effective way is by means of electricity, used in an electric needle by a skilled operator.

Care of the Hair. — The two main causes for falling hair are a tight scalp with a poor circulation and the presence of dandruff. The two important things to attend to, therefore, are massaging the scalp in order to promote the circulation, and keeping the scalp clean by daily brushing of the hair and shampooing every two or three weeks. Why does the groom spend so much time in currying and brushing his horse?

The nails. — Nails are a growth of the epidermis, and, like the epidermis, only the lowest cells near their roots are alive and receive nourishment. The root of the nail is in a kind of groove or fold of the true skin at the bottom of which papillæ are very numerous. The nail may be regarded as a very wide flat hair. The nail grows not only at

its root but along its bed, which is of true skin (Fig. 23). Hence, its thickness increases as it approaches the tip. If the epidermis is pressed back at the root, the nail may not be perfectly nourished, and a white speck or flaw is formed, which travels slowly along with the growth of the nail. It is said that the nail is renewed in three or four months. If you note the date of the appearance of a scar at the base of the nail and note when it has traveled to the tip, you can find whether this is true. Find whether or not a nail is transparent, by looking through the tip of the nail, held up to the light. The nails stiffen the ends of the fingers and aid in handling small objects. Can you pick up a pin without using the nails? Corresponding organs in the lower animals are claws and hoofs.

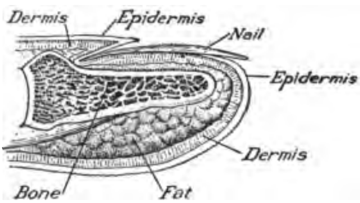

Fig. 23. — Section of nail and parts beneath.

In manicuring the nails a file should be used. Cutting makes them brittle. Biting the nails is often a sign of nervousness and should be controlled, not only because of the unpleasant habit but also because of the injury to the nails themselves. Proper care of the body involves manicuring the nails and this care should be given. A well-groomed appearance increases one's self-respect and commands the respect of others.

Indications of good health. — One may be not definitely sick and yet lack the feeling of good health. This is expressed at times as not being up to "par." Health is not only a condition of freedom from disease but also a quality of life and it is to our advantage to keep ourselves at the highest and best level of health attainable. In this connection there are certain indications of health that are valuable:

1. Consciousness of feeling well. Allied to this, of course, is the absence of pain.

2. Enjoyment of activity of muscle and mind. One is not at the highest point of efficiency if activity is not enjoyed.

3. Sound sleep with a feeling of being rested in the morning. One should be sleepy when tired out, and one is in normal condition in this respect if he can go to bed and sleep.

4. Normal appetite and normal digestion. The power to enjoy wholesome food, to eat and enjoy a good breakfast.

5. Power to remove the waste of the body without taking drugs.

6. Poise and control in the muscular movements of the body. This means the involuntary movement of breathing also, and requires that the individual breathe calmly, deeply, and regularly.

7. Ability to accomplish the work that lies ahead. This does not mean that all work must be successful, but there should be the feeling that there is achievement.

8. Throughout all these activities, the happy, cheerful disposition is a sign and indication of good health. This does not mean that one must go about with a smile or grin on the face, but a habit of meeting difficult tasks without fear or discouragement should be cultivated.

These eight indications are of value in that they point out the way of health, which is something more than mere absence of disease; it means abundant health of such a kind that one can do more work and also give and receive more happiness and enjoyment in the world.

APPLIED PHYSIOLOGY.

Exercise I

1. If a hair is pulled out, what determines whether it will grow again?

2. Why is linen used for towels?

3. What causes the hair to "stand on end" when a person is frightened or when an animal is cold?

4. What color of clothing is best adapted to summer? To winter?

5. How may rubber shoes make the feet moist?

6. State a fact which shows that the skin is a regulator of temperature.

7. Are wrinkles a sign that the skin is too tight or too large and loose for what it covers?
8. In what ways may a city and the body of man be compared?
9. Describe the division of labor in cells.
10. What are signs of health in the body?

Exercise II

11. Why does the heat seem more oppressive in moist weather?
12. Which should usually wear warmer clothing, a farmer or a merchant?
13. Which teeth are important for the development of the bones of the jaw and face?
14. In what respect do patent leather shoes resemble rubber shoes?
15. Why is baldness more common among men than among women?
16. What are the important principles in the care of the hair?
17. Why is a complexion considered beautiful when it is pink and fair?
18. What is the best means of improving the circulation in the skin?
19. Who is more apt to have a sincere nature, a person with a clean face and truthful complexion, or one who paints and powders?
20. What are the functions of the skin?

Exercise III

21. What are the causes of decay of the teeth?
22. Of what use is this information?
23. Did you ever know of a case of loss of health caused by changing the warm clothing of daily wear for the thin or scanty dress of a ball or party?
24. Why should we remove an overcoat or cloak when we go into a room?
25. Why is cold water better than warm water for the daily bath?
26. Explain how the wearing away of the outer cells of the epidermis contributes to the cleanliness of the body.
27. What is the effect of cold water upon the skin?

LABORATORY EXERCISES

Experiment 1. To study the structure and arrangement of the cell in an orange.

Material. — Navel orange.

Method and observation. — Peel the orange and separate a segment. Gently break open a segment and observe the cells filled with juice. In terms of animal tissues, locate the cell wall, the intercellular spaces, and the protoplasm.

Experiment 2. To study cellular structure.

Material. — Onion (sprouting), slide, microscope, toothpick, methylin blue, medicine dropper.

Method and observation. —

(*a*) Peel a thin piece of tissue from an onion root and place on a slide. Observe with low and high power and identify cellular structure.

(*b*) With a clean toothpick take a scraping of cells from the tip of the tongue or inside of cheek. Place scraping on slide and add one drop of methylin blue. Allow the stain to remain one minute and then remove the excess of stain by gently flushing the slide with water from a medicine dropper. Cover with cover glass and place slide under microscope. Identify cell wall, nucleus and protoplasm.

Experiment 3. To study cells and tissues.

Use prepared slides[1] showing different tissues and exhibit these under the microscope. Let the pupils see the main varieties.

GLOSSARY

Adenoids. — An enlargement of the connective tissue at the upper part of the throat where the throat and nose meet.

Artery. — One of the tubes that convey blood from the heart to the cells and lungs of the body.

Capillary. — A fine, slender blood tube with a hairlike bore. Capillaries are the smallest tubes for conveying blood. The arteries terminate in capillaries.

Castile soap. — A white hard soap made with olive oil. In making hard soap the alkali used is soda; if potash is used the product is soft soap.

[1] Permanent preparations of cells and tissues may be obtained from Bausch and Lomb Optical Company, Rochester, New York.

Cavity. — A hollow space within the body. The term cavity is used if this space is either actual or potential.

Decompose. — A separation into the chemical elements that make it up. Used to describe decay and disintegration.

Dentine. — The hard dense substance which forms the major part of the tooth.

Epiblastic. — The outermost layer in the developing embryo. It forms the skin, the hair, the teeth, and the nails.

Epithelium. — The tissues in which the cells are arranged to cover free surfaces and to form the active structural element of the glands that secrete. The arrangement of the epithelium is very orderly; epithelium of the mouth can readily be distinguished from the epithelium of the skin, stomach, liver, etc.

Excretion. — The discarded waste from the body. This waste matter is thrown off by the cells and in doing so illustrates the katabolic aspect of metabolism. Excretion is not to be confused with secretion, because, although both are produced by the cells of the body, the product of the former contributes to remove waste, and the product of the latter is useful in activities of the body.

Follicle. — A minute cavity, sac, or tube.

Gastric juice. — A thin acid fluid secreted by the glands of the stomach. These glands are composed of epithelium and produce hydrochloric acid and also pepsin and rennin. These substances form the chemical essentials in the juice and are responsible for its action.

Kidneys. — Two organs situated in the back part of the abdomen. The cells are mainly of epithelium and secrete from the blood as it passes through the kidneys the waste that forms the excretion known as the urine.

Membrane. — A thin sheetlike structure composed of epithelium cells and serving to line a cavity, tube, or follicle.

Nourishment. — That which sustains the life and promotes the growth of the individual.

Orris root. — The fragrant, violet-scented root obtained from several species of Iris, a plant with sword-shaped leaves and known in cultivation as fleur-de-lis.

Papilla. — A small nipple-like process.

Pellicle. — A thin film.

Perspiration. — The product of the secretion activities of the sweat glands in the skin. This exhalation is an excretion.

Pigment. — Any substance that gives color to animal or vegetable

tissues as exhibited in the skin, the hair, the eye, and the leaves and flowers of plants.

Precipitated chalk. — A heavy, fine powder. It is obtained by precipitating calcium carbonate. It is much used in tooth powders.

Pulp. — The soft tissue composed of blood vessels and nerves and found within the cavity of a tooth.

Saliva. — A tasteless, odorless, slightly viscid, alkaline secretion of the salivary glands of the mouth.

Secretion. — A substance separated from the blood by the cells developed for that purpose. This substance plays some useful part in the body. It is to be distinguished from the term excretion.

Sensitive. — A quality of being easily affected by outside operations or influences.

Serous membrane. — A delicate tissue composed of flattened cells that line the large cavities of the body. These cells secrete a fluid called the serous fluid. It is similar to the serum of blood.

Socket. — A cavity or opening especially adapted to receive some correspondingly shaped piece.

Vein. — A muscular and tubular vessel that conveys blood to the heart. It is distinguished from an artery by having less muscle and elastic tissue in its wall and by carrying blood to the heart; the artery carries blood from the heart.

CHAPTER III

TISSUES (Continued)

I. Connective Tissues.
 White fibrous tissue
 Yellow elastic tissue
 Adipose tissue
 Cartilaginous tissue
 Osseous tissue → bone

II. Muscular Tissues.
 Oxidation and muscular action
 Oxidation and burning
 Oxidation in the body and in a machine
 Points of similarity between the human body and a steam engine
 Points of difference between the human body and a steam engine
 Muscular contraction and chemical change
 Alcohol and muscular efficiency

III. Nervous Tissues.
 Nerve structure
 How nerves and muscles work together

IV. Building Good Tissues.
 The effects of alcohol
 The effects of drugs
 Stimulation *vs.* construction

Connective tissues. — Connective tissue serves the body by affording support to its several parts. The fibrous tissue, which binds the cells together and supports the various organs, is also called connective tissue, but it is distinguished from the connective tissues in general by the name "white fibrous connective tissue." In some of this tissue there are

yellow elastic fibers, hence the name "yellow elastic connective tissue" is used. The tissues that are to be grouped under the connective tissue heading are:

1. White fibrous tissue (Fig. 24).
2. Yellow elastic tissue (Fig. 24).
3. Adipose (fatty) tissue (Fig. 25).
4. Cartilaginous tissue (Fig. 26).
5. Osseous (bony) tissue.

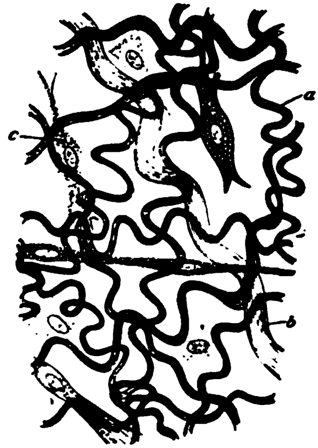

FIG. 24. — Connective tissue taken from beneath the skin. *a*, yellow elastic fibers; *b*, white fibers; *c*, cell which forms the kind of fiber shown in *b*.

White fibrous tissue. — White fibrous connective tissue consists of cells that have very small nuclei and cell bodies that are prolonged into fibrous strands (Fig. 24). These fibers may be considered as a development of the cell (Fig. 24, *c*). They are not elastic. This tissue forms the ligaments,* structures that hold the ends of bones together, making a joint.

Yellow elastic tissue. — Yellow elastic connective tissue is found scattered among the white fibers (Fig. 24). It is relatively large in amount in the walls of the blood vessels, and in the firm part of the ear.

Adipose tissue. — This soft tissue furnishes cushions for delicate organs like the eye, forms a layer under the skin, thus rounding out the form and storing up food for the use of nerve, muscle, and other cells. The fat is first deposited in the form of minute globules in the white connective tissue cells; these globules gradually increase in size. Fatty tissue is, therefore, nothing more than fat deposited in the cell body of white connective tissue (Fig. 25). What is lard? Tallow? Suet? In what tissue do these substances lie?

Cartilaginous tissue. — Some parts of the body require tissue having something of the rigidity of bones, yet capable

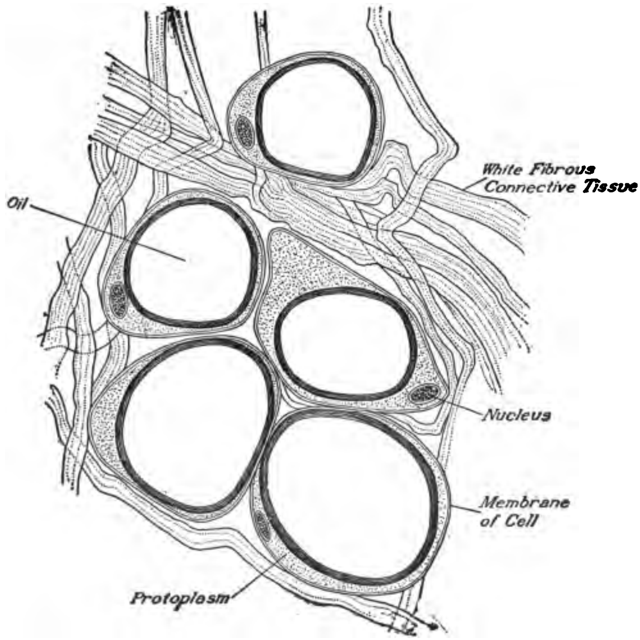

Fig. 25. — Fatty tissue. Five fat cells, held together by bundles of connective tissue.

of bending under pressure. This purpose is fulfilled by the elastic tissue called cartilage. A piece obtained fresh from an animal is seen to be covered by a thin fibrous membrane, which is reddish because it contains blood vessels. When this membrane is stripped off, the cartilage shows no sign of redness, that is, it contains no blood vessels. Under the microscope, cartilage is seen to be composed of cells, often arranged in pairs (Fig. 26), which suggests the fact that they have been formed by the division of one cell. The substance between the cells is the product of the cells, has been de-

posited by them, and is called the intercellular substance or matrix.*

Cartilage may be readily felt in the nose at the tip, and in the ears. The cartilage of the ear contains an abundance of elastic fibers. The cartilage between the divisions of the vertebral column contains both yellow elastic and white fibrous cells. It is, therefore, in nature, elastic and tough.

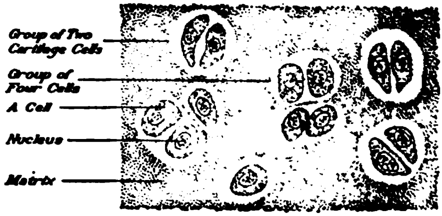

FIG. 26. — Cartilage. A thin section, highly magnified.

Osseous tissue. — Just as white fibrous tissue supports and holds in place the delicate cells and fibers of the organs, so bone and cartilage support the complete organs and hold them in their places in relation to one another. Cartilage and bone are closely related as to location, function, and development. For example, the flat bones, in infancy, forming the roof and sides of the skull, are soft and flexible, being composed of cartilage, except for a small patch of bone in the middle of each. As growth proceeds, the bones touch and interlock, replacing the cartilage. If a bone is broken, the new part, as it forms, is first cartilaginous and afterward it is replaced by true bone. Growth in length of the bones takes place in the cartilage at the ends of the bones. A person ceases to grow in height at about the age of twenty-five on account of the ossification of the cartilage.

There are machines for increasing one's height. They work by stretching the spine. Many persons could become taller by standing and walking in an erect posture. After the ossification of the cartilage in bone, however, increased height can only be secured by making the body more erect, either by machines or by exercise.

All bones are covered by a thick fibrous tissue called periosteum.* This contains the blood vessels which pass into the bone to supply nourishment and also bone cells which by development increase the circumference of the bone.

Muscular tissues. — The cells constituting the body were likened to a human community or city. Such a comparison helps us to realize how complex is an animal body, and how wonderful are the processes of life. But the relation between the cells is much closer than that between the individuals of a community. There is a marked difference, however. The human being can move as a whole, can change place in space, and can act with the harmonious assistance of the organs of the body. *The energy* * *stored in the body enables it to do these things*, and the two tissues that chiefly expend the energy and give us the ability to do things, to act, are nervous tissues and muscular tissue. In mechanical terms, therefore, the body may be called a neuromuscular mechanism.*

Oxidation * *and muscular action.* — This energy in muscular action arises from a kind of combustion* or chemical reaction, and resembles, in its source, the energy of the steam engine. That something besides wood or coal is necessary to a fire can be shown by shutting off entirely the draught of the stove. Fire and all other forms of combustion depend upon a process called oxidation. This consists in the uniting of oxygen, the active element of the air, with carbon,* hydrogen,* and other elements in wood, coal, etc. Bread, meat, and other foods contain these energy elements also. That there is carbon in sugar can be easily proved by charring sugar upon the stove, the charcoal thus produced being a form of carbon. Complex organic* food compounds containing these elements are taken into the body through the digestive organs and broken up into smaller units which may be stored in the body cells ready for union with oxygen when

action is needed. The oxygen enters the body through the lungs and is carried to the tissues by the red blood cells of the blood. Oxygen is not stored in the body but is taken in in response to the needs of the body for oxygen.

Oxidation and burning. — The body resembles a locomotive in having warmth and motion as a result of the union of fuel and oxygen; but it differs from the locomotive, since the intelligent engineer is an integral part of it, and since the oxidation in the body is in the presence of moisture, and so gradual that it is not a true fire accompanied by light. Moreover the body can repair itself as it wears out, and the engine cannot. The energy stored in the body is used more economically than any steam engine can use fuel.

Oxidation in the body and in a machine. — There are points of similarity and points of difference between the body and the machine. Too often the differences are not noted. The human body is very complex, and the effect of any particular process is so profound that great care must be exercised to avoid stating too positively what any effect will be. There are people who are willing to state what the effect of a certain exercise on the body will be, and they talk about educational exercise and hygienic exercise. In most instances they are unfamiliar with the real meaning of education and hygiene, and they do not appreciate how very difficult it is to predicate the effect of any particular exercise. That the body resembles a machine there can be no doubt, but it is quite as important to remember that there are very important differences.

Points of similarity between the human body and a steam engine.

1. Both require fuel.

2. Both transform energy from rough masses. The energy in the wood and coal is potential* and in the steam engine it is changed into kinetic* energy in the form of heat. The energy in meat and potatoes and other foods is potential, and by digestive processes it is changed into kinetic energy.

3. Both produce waste products and both must have this waste removed. It is just as important to keep the human body free from its waste as it is to keep the ashes out of the furnace box. Many people take better care of the furnace in the home than they do of the furnace in their own body. This is largely because of ignorance and not because of lack of interest.

4. Both are of complicated mechanism.

5. Both need repair. The engine cannot repair itself, but the body in many particulars can repair injuries. It is important to remember that the body cannot repair all injuries without the assistance of man. An inflamed appendix,* a broken bone, cancer, and many other instances of injury need the trained hand and intelligence of the surgeon. There are people who attempt to repair the body by taking "patent medicine," and yet they will send for a mechanic to repair the broken pump or the blacksmith to repair the broken wheel of the wagon. These people foolishly attempt to tell what is wrong, and to treat a mechanism that is very complicated; on the other hand, they would not think of such procedure in repairing a simple mechanism like a pump, wagon, or automobile.

6. Both need rest. Great industrial plants often have two sets of power engines so that they can rest one set on alternate weeks. Men are saying to-day that they can do twelve months work in ten months, but they cannot do it in twelve. Rest is needed.

7. Both need exercise, activity. This similarity is very important. In each case the right kind of activity is essential for the most efficient action.

8. Both need intelligent care. We need to take as good and as intelligent care of our bodies as the engineer takes of the steam or gasoline or electric engine.

Points of difference between the human body and a steam engine.

1. A human body requires a greater variety of fuel. The steam engine will burn coal and will do its best work on that particular kind of supply. The human body will not do its best work on meat or vegetables or nuts alone.

2. A human body is never entirely inactive. Even at night when asleep, the human body is working, carrying on the processes which keep the body alive.

3. A human body has the power of self-development. On the physical side it starts with a single cell and grows to maturity. Under intelligent direction, this growth may be directed to produce

a very fine type of being. This power of self-development makes the human body very much more interesting than the steam engine.

Muscular contraction and chemical change. — How does the oxidation of food produce motion? We learn that the amœba and other one-celled animals can change their shapes. Many of the cells of the body have lost this power, but the muscle cells retain it. Figures 79, 80, 81 show various types of muscle cells. They differ in the shape of the cells and to some extent in the structure of the cell, but they are all alike in that they get broader and shorter when they contract. The food that is most easily burned in the muscle is sugar. Sugar is stored in the muscle in the form of glycogen,* and when a nerve impulse comes to the muscle it causes the sugar to undergo a chemical change. This chemical change in the muscle produces heat (see Laboratory Experiment, page 30) and the heat causes such change in the muscle cells that the cells become shorter and broader. This change is called the muscular contraction. If sugar is deficient in the muscle, it is possible for the cells to burn fat* and protein.* The waste from this combustion causes the fatigue* that is experienced after muscle work, and this waste may be likened to the ashes or clinkers left in the furnace after the coal has burned.

The duration of a muscular contraction varies in different animals. The following table shows the duration of a simple muscular contraction:

Insect	0.003 second
Rabbit	0.070 second
Frog	0.100 second
Terrapin	1.000 second

The height of a muscular contraction depends upon the strength of the nerve impulse and whether the muscle is fresh or fatigued. In other words it depends upon how hard one tries and upon how much work has been done. The

strength of the contraction, however, is greater after some work has been done. For this reason, athletes always warm up before trying for a record or running a race or playing a game. It is greater if one has had plenty of sleep and rest at the proper interval, before the activity. Figure 27 shows how fatigue occurs in the muscle of the finger. Using an

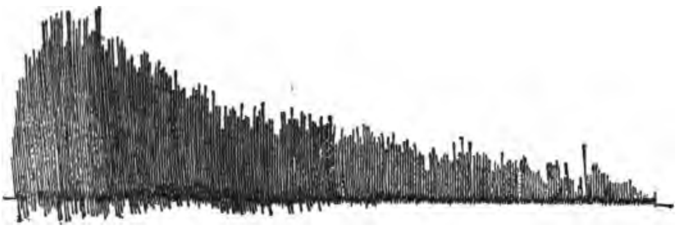

FIG. 27. — Tracing of muscular contraction showing a decrease in muscular power (fatigue).

ergograph,* each contraction of the finger is recorded on smoked paper. The increase and decrease in muscular efficiency is to be noted.

Alcohol and muscular efficiency. — People have had the erroneous idea that alcohol* helps the individual to do work. This belief arose because of the drug effect of the alcohol

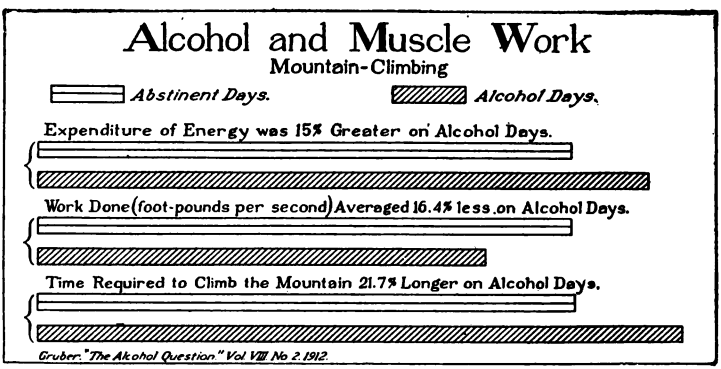

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FIG. 28. — Alcohol decreases the ability of man to do muscular work.

upon the brain.* It has been shown that from 8 to 10 per cent less work is done when alcohol is taken, even in such small amounts as that present in a pint of beer. Professor Durig, a mountain climber, experimented on Mt. Bilkencrat in the Alps with alcohol to determine the effect upon muscular efficiency. On the days when he took alcohol amounting to 2 or 2½ glasses of beer, "his watch showed that it took 21.7 per cent longer to reach the top of the mountain than on the days when he took no alcohol" (Fig. 28).

It has been shown that alcohol impairs the efficiency of athletes in all contests. A test was made at a marathon

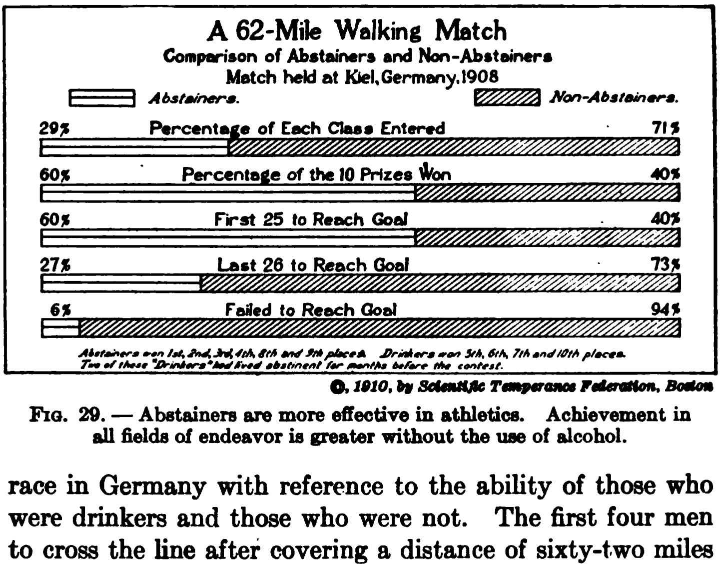

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FIG. 29. — Abstainers are more effective in athletics. Achievement in all fields of endeavor is greater without the use of alcohol.

race in Germany with reference to the ability of those who were drinkers and those who were not. The first four men to cross the line after covering a distance of sixty-two miles were abstainers. More than half of the drinkers fell by the way and only two of the abstainers (Fig. 29). In baseball the same test has resulted in managers insisting upon abstinence. Connie Mack, manager of the famous "Athletics" in the years when they twice won the championship in both leagues, said, "Baseball men are not now of the drinking

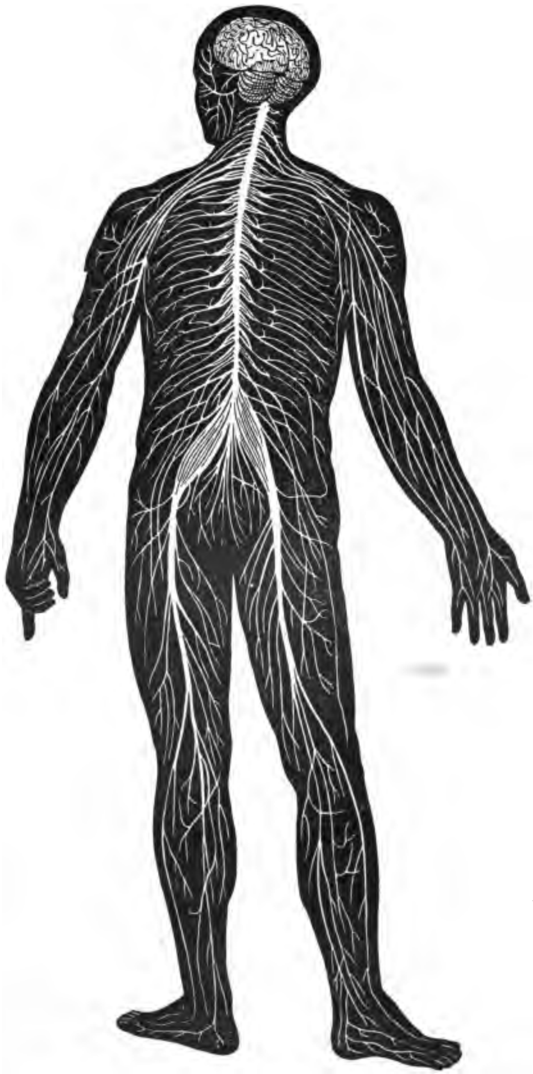


FIG. 30. — The general arrangement of the nervous system (viewed from behind). Showing the brain, the spinal cord, and the chief nerves that branch from it.

class. The fact is that a big-league player has to be in trim day in and day out or he is sent to the minors. It is the survival of the fittest." He who would excel in the world must leave alcoholic drink alone.

Nervous tissues. — Knowing, as you do, how microscopic the cells are in size, what would you think if you were told that there are cells in the body that have parts which extend several feet in length! There are cells with branches which reach, for instance, from the spinal cord to the toes (Fig. 30). A mass of nerve tissue called the brain occupies almost all of the skull, and the lower part of this nerve tissue forms the spinal cord,* or spinal marrow. Nerve tissue forms also the glistening white cords, called nerves, going from the brain and spinal cord to all parts of the body (Fig. 30). Have you seen a hog's brain or the brain of an ox? However complicated nerve tissue may seem to be, it is found to consist of nerve cells and their branches, called nerve fibers. Some cells are arranged in a distinct mass called a ganglion (Fig. 37).

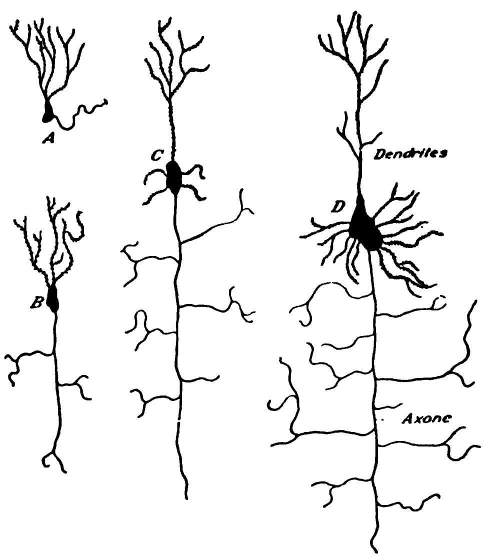


FIG. 31. — Nerve cells from different animals. *A*, frog; *B*, lizard; *C*, rat; *D*, man (after Ramón y Cajal).

Nerve structure. — A nerve consists of a great number of cell-branches or nerve-fibers, just as a number of telephone wires are sometimes

bound together in a cable. Nerve cells grow, become active and die, like other cells, and like other cells they consist of protoplasm with a nucleus and nucleolus. A number of processes branch off from them, some cells giving off only one or two, others many (Fig. 31). One of these processes, larger, longer than the others, forms the nerve fiber or axone. The axis, or central part of the fiber, is a continuation of the jellylike protoplasm of the cell; this core is the essential part of the fiber. The axis is surrounded in most fibers by a sheath of fatty material (Fig. 32). This is for nourishment and protection of the axis, and it is this that gives to the fiber its characteristic ivory-white appearance. The whole is strengthened by being inclosed in a thin, delicate sheath of connective tissue. Some of the nerves go to the muscles, and passing between the bundles of fibers, soon divide into branches, for we have seen that the nerves are bundles of separate fibers. They subdivide in the muscles till they ultimately send a single nerve fiber to each individual muscle fiber.

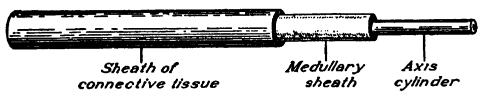


FIG. 32. — Scheme showing structure of nerve fibers. How does it resemble the insulation of a copper wire used in electric wiring?

How nerves and muscles work together. — Suppose you put your hand on a hot stovepipe or poker; it is immediately jerked away. How does this wonderful thing happen? The heat of the iron causes a disturbance in a nerve fiber ending just under the skin of the finger. This disturbance travels rapidly along the axis, or core, of the nerve, and is called an impulse.* It is not a visible change, but some influence that travels from particle to particle. It resembles electricity somewhat, but some physiologists think it is like a wave of chemical change, running along the nerve faster than a railway train can run. It reaches a nerve cell in the spinal cord.

The disturbance there causes the cell to send out impulses along its other branches or fibers.

Some impulses (Fig. 33) are sent down the arm again to its muscles, causing them to contract, and the arm is jerked away, as we say, by reflex action, or action without will on our part. Other impulses go at the same time to the brain, and we become conscious of what has happened. (The nerves which carry impulses to the nerve cells (afferent) are called sensory nerves, or nerves of feeling, and those which carry impulses from the cells to the muscles (efferent) are called motor nerves, or nerves of motion.) Nerve fibers transmit impulses, but do not originate them. An impulse in a nerve can be excited by a pinch, a prick, electricity, a drop of acid, a hot wire, a cold object, or a thought. Reflex action always occurs on account of some influence from the outer world but voluntary action comes from activity in the brain.

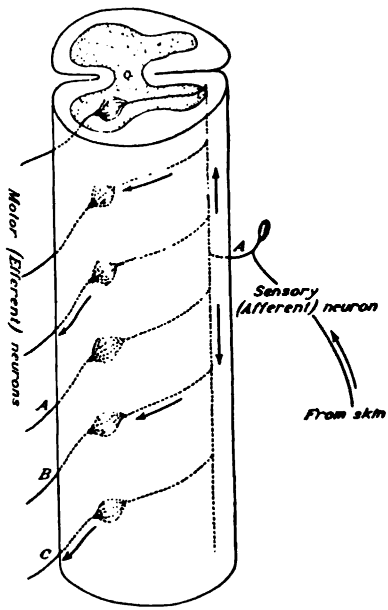


Fig. 33. — Reflex arc (after Kölliker). The sensory impulse comes from the skin and is directed out to the muscles over the motor neurons and to the brain by the sensory brain paths.

Suppose you step out of a warm house into a cold wind. The face immediately blanches or turns white. Let us see how this can be accounted for. There are muscle fibers in the walls of the blood vessels. The cold air excites impulses in the sensory nerves of the face, which travel to the enlarge-

ment at the top of the spinal cord just at the base of the brain, called the medulla oblongata (Plate VI). Here the impulse reaches a nerve center which sends it along another set of nerves that go to the muscle fibers in the walls of the blood vessels, causing them to contract, and the face turns white. Thus we see how closely related are these two tissues.

If we consider that the nerves reach almost everywhere in the body, and that the muscles of the body weigh nearly as much as all other tissues together, we realize how important these tissues are. Let us count up some of the activities in which the muscles are necessary: swallowing, digesting food, breathing, blushing, writing, walking, talking, looking, tasting, chewing, frowning, smiling, laughing, circulation of the blood. There are only a few things, such as hearing, smelling, and feeling, that can sometimes be accomplished without muscles. In their functioning, muscle and nerve cannot be separated. Body reacts on mind; mind controls the body.

Building good tissues. — As you have learned, all of the tissues are built, maintained, and repaired by living cells. Life and health depend upon the proper and continuous activity of these cells, and anything that aids in this activity strengthens the body and prolongs life; anything that injures them or interferes with their activity, impairs the health and shortens life. Growth and repair of tissue are prompted by sunshine, by fresh air, by drinking plenty of pure water, by good food, by active and happy occupation. Weakness and injury of cell and tissue result from depriving the body of these conditions. When these essential conditions are absent, the first step in the restoration of health is to restore these conditions, and adapt the daily life to them.

Injury to tissues shortens the life of the individual. With the knowledge of the injurious effect of alcohol upon the tissues of the body, life insurance companies are refusing

insurance to those who are drinkers. Intelligent persons would not sell ten to fifteen years of their life for a portion of alcohol; statistics show that abstainers live longer.

The effects of alcohol. — Arthur Hunter, of the New York Life Insurance Company, in a report (May 1916) of the Department of Health of New York City, shows that the death rate among abstainers is from 10 to 30 per cent lower than among non-abstainers. This report agrees with the British statistics, which also show that alcohol has an unfavorable effect on longevity and that total abstinence increases longevity. The Actuary of the Mutual Life Insurance Company, after an experience of fifteen years, came to the following conclusion:

> "The difference between those who drink beer and those who drink water is unmistakable, while the loss on beer drinkers has been almost the same as among wine and spirit drinkers."

The effect of drugs. — The physician uses drugs in illness to produce certain effects in the body. He can change the rate of the heart, the force of the blood pressure. He can stimulate or quiet the nervous system. He can increase the activity of the sweat glands, cause changes in the intestines, and relax the muscles. But all the effects are accomplished because of some condition existing in a sick body. The giving of medicine must be preceded by a diagnosis of the illness.

There are some people who are so ignorant of the human body that they are willing to treat themselves and even their friends with virulent* drugs and patent medicines. These persons frequently recommend a drug or endorse a headache powder because it relieved a certain friend, but they fail to realize that every case of illness varies in a marked way, and that the same symptoms* may be present for different diseases.

Some people use drugs because they have formed a habit.

Drug habits are very injurious because the dose must constantly be increased to have the desired effect, and in time the person becomes dependent on it. Morphin, cocain, heroin, headache powders, bitters, and tonics are preparations that are injurious when used carelessly. They are only to be used on prescription by a physician.

Stimulation vs. *construction.* — The body does not usually need stimulation from alcohol or drugs. The stimulating effects of exercise, wholesome food, fresh air, good companions are far more valuable. Alcohol must not be thought of as a stimulant, because it does not construct the body but it destroys. This is one reason why a person who has been used to alcoholic drinks recovers less rapidly from an accident or surgical operation than one who uses none. Sick benefit societies in England and Australia have shown in records that members in the abstaining societies have about half as much sickness as those in the non-abstaining societies.

In general, it may be stated that care of the body with reference to hygienic living is the best kind of advice to give to people who are continually ailing. Sickness that requires a physician is sometimes unavoidable, and in such a case care should be taken to call a good physician, and his directions should be implicitly followed. Self-drugging by the public is considered by some the most fruitful cause of disease in the United States. "Mind cures" and kindred ideas often do more by rescuing victims from poisonous drugs than through their calming effect upon the mind.

APPLIED PHYSIOLOGY

Exercise I

1. The arteries contain more of the yellow fibers of connective tissue than the veins. Which have the more elastic walls?

2. Does fat accumulate in the body within the cells or outside them?

3. How can one "add a cubit to his stature" after the age of twenty-five?

4. What arguments can you present that may show that alcohol causes a loss in efficiency to the user?

5. Does the body take up oxygen? If it is desired to increase the process of oxidation in the body, how can this be accomplished?

6. In what respect does the body differ from a machine?

7. Which animal can contract its muscles the more quickly, a bee or a frog?

8. Why should there be "warming up" exercise in the gymnasium before the main part of the gymnastic lesson?

9. What part of the nerve cell is the nerve fiber?

10. What is meant by the statement that body reacts upon mind and mind controls body?

LABORATORY EXERCISES

Experiment 1. To study a one-celled organism with reference to its

(*a*) structure
(*b*) reaction to stimuli
(*c*) properties

Material. — Hay infusion,[1] pipette, glass slides, cover glasses, microscope, alcohol, and medicine dropper.

Method. — With the pipette draw a few drops of the scum which collects on the hay infusion. This scum usually contains a great number of single cell animals, called paramœcia.* Place a drop of this material on a slide, cover with a cover glass, and examine the specimen under low power of the microscope.

Observation. —

1. What is the structure of the organisms seen? Is there a definite shape?

2. Do they move? Do they move with a definite end forward? Do they move in any definite direction?

3. Add a drop or two of alcohol at the side of the cover glass. What happens to the movement of the organism?

[1] Instructions for making hay infusion. Obtain, from the side of a river or pond, some grasses that have grown on the water's edge. These dry grasses will have on their stems organisms of the single cell type. Place these grasses in a glass jar with water and set the jar in the window of the class room. In two or three days organisms can easily be obtained.

4. Place a heated needle at one side of the cover glass. Does this produce movement in any particular direction?

5. Are there paramœcia around an air bubble? What do they get from that? Is an air bubble necessary for the obtaining of oxygen by this organism?

6. Are there any paramœcia undergoing division? Reproduction in this organism occurs when it is mature and follows definite laws of division. Draw paramœcia showing structure, reaction to stimuli, and properties.

Experiment 2. To demonstrate chemical and electrical action with reference to muscular and nervous activity.

Material. — Test tube, pieces of zinc, sulphuric acid, zinc strip, copper strip, current key, electric bell or galvanometer.

Method and Observation. —

(*a*) Into a test tube place several pieces of zinc, add some water until the zinc is covered. Feel the test tube and notice any change. Pour in sulphuric acid. Again feel the tube and note the change. The action resulting is chemical in nature and heat is produced. The energy formed here in this chemical action expresses itself as heat. The chemical action in muscle expresses itself as heat and the two actions are similar.

(*b*) Make a voltaic cell by placing zinc and copper strips in a twenty per cent solution of sulphuric acid. Connect wires with the end of each strip and fasten the two wires by means of a key to an electric bell or galvanometer. When the key is closed the bell will ring or the needle will move. The energy generated here produces heat, as can be determined by feeling the voltaic cell, but the characteristic effect is the production of an electric current. The chemical action in the nerve cell produces a nerve impulse which is similar to an electric current.

GLOSSARY

Alcohol. — A volatile, inflammable, colorless liquid of a penetrating odor and burning taste. The chemical formula is (C_2H_5OH). It is derived principally from sugars and sugar-giving substances such as corn, potatoes, and grapes. Dr. Frederick Peterson classifies it as a poison in the following words, " Alcohol is a poison. It is claimed by some that alcohol is a food. If so it is a poisoned food. Alcohol is one of the most common causes of insanity, epilepsy, paralysis, diseases of the

liver and stomach, dropsy, and tuberculosis." *Collier's Weekly*, Nov. 30, 1907.

Appendix. — Vermiform appendix is a wormlike organ situated at the junction of the small and large intestine, on the right side of the abdomen. It is the seat of the disease called by the name appendicitis.

Axone. — Sometimes spelled axon, and known as the axis cylinder of the nerve cell. It is the long process that runs from the cell body and joins the processes of the nerve cell with which it connects.

Brain. — The organ of the mind. It is an enlarged portion of the nervous system, located in the skull. It is the organ of consciousness, of thought, and of voluntary action. It receives and sends impulses and regulates and controls the functions necessary to life.

Carbon. — An element found in all organic substances. It is present in all foods and usually found in chemical combination with hydrogen and oxygen.

Combustion. — The action or process of burning. The fire in the stove illustrates combustion. In the human body combustion is much slower and the continuous combination of chemical substances that produces energy for work is similar to the combustion in the steam engine that produces energy in the form of steam.

Energy. — The quality by reason of which anything is able to act. It represents force. In physics it is the capacity for performing mechanical work. There are different forms of energy and one form may be changed into another. No energy is ever lost.

Ergograph. — An instrument for recording work done by the muscles. Mosso, an Italian physiologist, invented the first ergograph. The word comes from *ergon*, meaning work, and *graphos*, writing.

Fat. — One of the food elements.

Fatigue. — A condition of diminished ability to do work. The amount of fatigue varies under different conditions. Fatigue of muscle can be measured by the ergograph.

Glycogen. — A complex compound of sugar.

Hydrogen. — A colorless, odorless, tasteless gas represented in chemistry by the letter (H). It is very abundant in nature, occurring in combination with oxygen to form water (H_2O) and with carbon (C) to form many organic compounds.

Impulse. — Represents the change set up in nerve fibers by means of stimuli coming either from the endings of the nerve in the cells of the body or from the brain or spinal cord. The impulse is a force that travels along the nerve. What its nature is has not been definitely determined, but it is thought to be something like an electric current.

Kinetic energy. — The energy of action. It belongs to every body in motion and is to be distinguished from potential energy.

Ligament. — A band of firm, compact, fibrous tissue that closely binds related parts together. It is most often found binding the ends of two bones together to form a joint.

Matrix. — The formative cells from which a structure grows.

Mechanism. — The structure by means of which action is secured. The neuro-muscular mechanism refers to the arrangement between the nerves and muscles by means of which certain types of action are secured.

Organic. — Relates to organism and pertains to animal and vegetable life. Also used to designate compounds. An organic compound contains carbon and is distinguished from inorganic compounds which contain metals in their composition. Some organic compounds may contain metal, as for example, hæmoglobin, which contains iron.

Oxidation. — The process of uniting of some chemical substance with oxygen. All combustion in the body is an example of oxidation and the ability of oxygen to unite with chemical compounds and cause combustion with the production of energy is oxidation.

Paramœcium. — A small animalcule with an elongated, ciliated body. The mouth is in a pit on the under surface of the body.

Periosteum. — The fibro-vascular membrane that covers and nourishes bone. In this membrane runs the blood vessels which carry nourishment to the bone.

Potential energy. — The energy that is in the substance or mechanism but not as yet in action. It represents the energy that is available for action. The energy in food is potential but when the food undergoes oxidation and combustion results, the energy becomes kinetic.

Protein. — One of the food elements.

Spinal cord. — That part of the nervous system which lies within the canal formed by the openings in the bodies of the vertebræ. Into this structure come the nerves from all parts of

the body; at the base of the skull it joins with the brain. The brain and spinal cord are called the cerebro-spinal nervous system.

Symptom. — A sign or indication that serves to point out the existence of something else. Pains in the body are symptoms of a condition of abnormality in the body.

Virulent. — Having the characteristic of strength or poison. A virulent infection is one that is severe and dangerous because the poison from the disease is so strong.

CHAPTER IV

ORGANS FORMED FROM TISSUES

I. The Different Systems in the Body.
II. Organs of the Muscular System.
III. Organs of the Skeletal System.
IV. Organs of the Digestive System.
V. Organs of the Respiratory System.
VI. Organs of the Circulatory System.
VII. Organs of the Nervous System.
VIII. Organs of the Excretory System.
IX. Organs of the Reproductive system.

The different systems in the body. — We have learned how the different types of body cells were grouped in tissues to form organs. This grouping serves the purpose of bringing together the cells of one kind for a specific task and is similar to the collective work of men and women in an industry. In the body we find muscle cells arranged in large masses for the purpose of contraction; in a similar way in human society we see the crew of a railroad train working together to accomplish some result.

But the organization of the body is more wonderful, even, than indicated above. Organs composed of cells of the same or different variety are coördinated into systems that carry out important life processes. A railroad system is an organization of men and women for the purpose of carrying on transportation. It includes in addition to its executive and administrative officers, trackmen, clerks, telegraphers,

trainmen, repair men. In similar fashion the digestive system, which is concerned with the preparation of food in the body for the use of the body includes in its working organization teeth, salivary glands, stomach, liver, gall bladder, pancreas, intestine, and colon. Not all of the bodily systems have so many different organs coöperating. The muscular system is composed entirely of muscles; the nervous system comprises brain, spinal cord, and nerves. But whether the bodily systems are composed of the same kind of organs or of many different organs, they are all alike in that the organs coöperate in the system to accomplish a specific result. We recognize in the body eight systems. They are the muscular, the skeletal, the digestive, the respiratory, the circulatory, the nervous, the excretory, the reproductive.

Organs of the muscular system. — The organs of the muscular system are the muscles attached to the skeleton (Figs. 90, 91). These muscles are concerned chiefly in performing movements necessary in work and play. We have in this system of muscles an arrangement, so coördinated that movement of the entire body or of parts of the body may be produced readily and efficiently. We shall learn later of some of the separate muscles in this system, but it is sufficient at this time to classify them in the following groups: Muscles of the head and neck, back, chest, abdomen,* arms, and legs.

There are other muscles in the body, especially in the walls of blood vessels and in the walls of hollow organs as the stomach and intestine, but the muscles so situated are concerned in the work of other systems and are not to be classified in the muscular system.

Organs of the skeletal system. — The skeletal system (Fig. 43) comprises the bones of the skull, vertebral column, thorax, shoulder girdle, pelvis, arms, and legs. These bones are assembled in a definite order and are held together by

ligaments. The bones vary in shape, size, and function, but they are all concerned in forming a framework for the structure of the body.

Organs of the digestive system (Plate III). — The organs of the digestive system are arranged so that the food taken

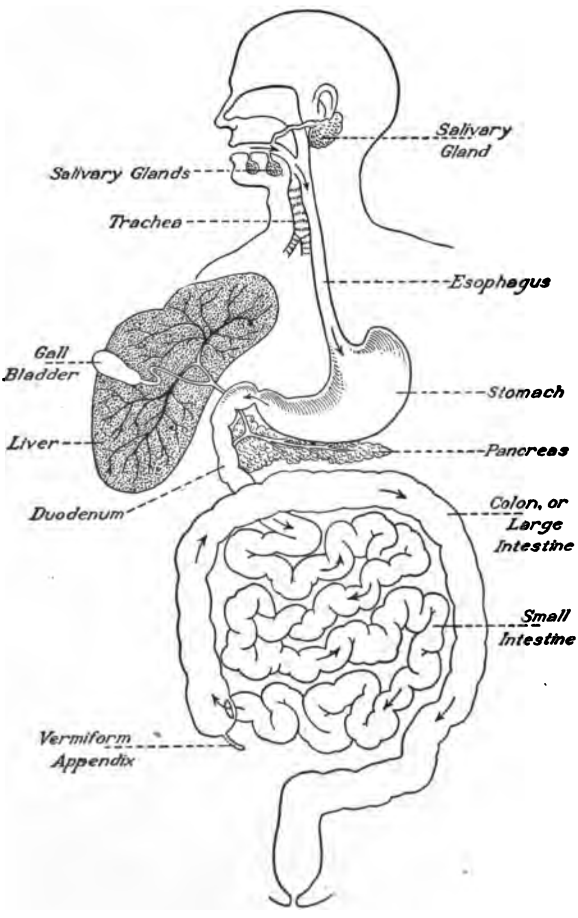


Fig. 34. — The digestive system.

into the mouth must pass along a certain tract and receive the action of the secretions of the organs along the way. Study the diagram in Figure 34 and name the organs. From this study it will be seen that the digestive system is made up of many different organs and in this respect it is unlike the muscular or skeletal systems. But it is similar in that it is an organization of organs for the accomplishment of a specific function. The function in this system is digestion. The organs are teeth, tongue, salivary glands, esophagus,* stomach,* liver,* gall bladder,* pancreas,* small intestine, large intestine. After the usable parts have been taken from the food, the remainder or waste is removed from the body. This waste should be removed daily and regularly or the health will be impaired.

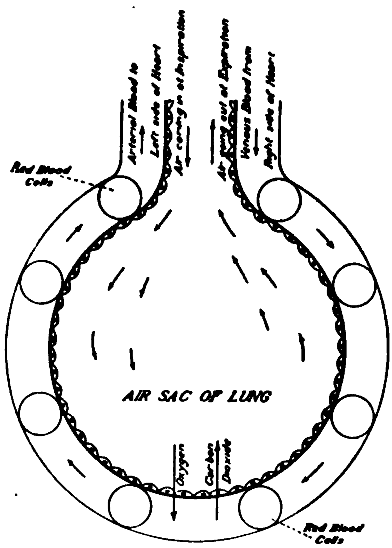


FIG. 35. — Diagram of respiratory mechanism in lung showing how the blood comes in contact with an air sac and thus receives oxygen and gives up carbon dioxide (modified after Adami and Nichols).

Organs of the respiratory system. — In the case of the amœba and paramœcium, which have only one cell, it is possible for oxygen and carbon dioxide to pass directly through the cell membrane. In higher forms, where so many cells are situated below the surface, a means must be provided for getting oxygen to the cells and removing the carbon dioxide. This is accomplished by the respiratory system. The organs of this

system are nose, larynx,* trachea,* lungs, and the muscles of respiration, the diaphragm* and intercostals.* This system provides for getting air into and out of the lungs but it is dependent upon the circulatory system for conveying the oxygen of the air from the lungs to the cells of the body (Fig. 35). Study the structures in Plate III and tell what they do.

Organs of the circulatory system. — The simplest circulatory system would be one in which there is a tube that contracts and, by the aid of a valve, forces on the fluid within the tube. The water supply system of a city is a means of water circulation in which the pumps at the station, the water mains traversing all sections of the city, and the running water are the essential parts. The essential organs of the circulatory system of the body are the heart, blood vessels, and blood. In the city water system there are engineers who run the machinery that pumps the water; in the body there are nerves and chemical substances that increase or decrease the rate and force of the heart's beat. These controlling agencies are very important but they do not constitute a part of this system. They illustrate the harmonious action between different systems and one of the ways in which the nervous system coördinates and controls all. Name the parts in Plates III and VIII and trace the blood from the left side of the heart until it reaches the right leg. Trace it from the stomach through the liver and back to the heart.

Organs of the nervous system (Plates VI and VII). — The simplest nervous system is one in which a stimulus is carried along a nerve to a nerve cell and the response follows (Fig. 36). If the central cell or mass be joined to other masses, it is possible for a stimulus to come in from one part and go out at another at a different level of the spinal cord (Fig. 37). Suppose that the first neural mass enlarges and takes control over all the other

masses and directs their activities. In this arrangement we have an illustration from comparative anatomy* of the

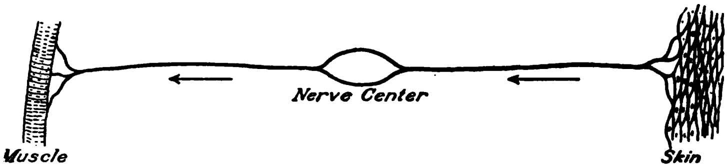


FIG. 36. — Diagram of simple type of nervous system. Stimulus coming from the skin is sent by the center* to the muscle.

evolution* of the nervous system from a simple type to a complex type as seen in man. The nervous system has

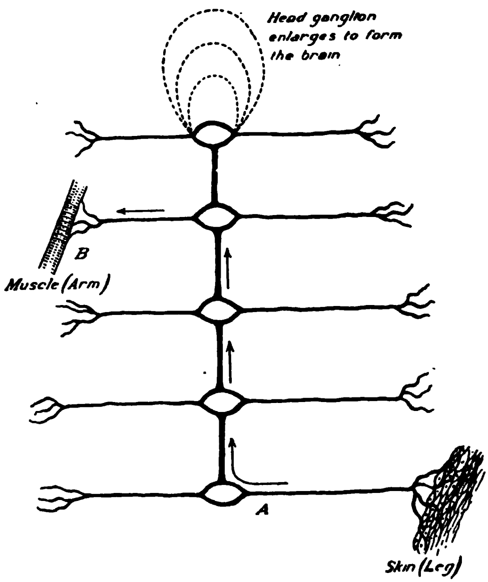


FIG. 37. — Diagram of a simple type of nervous system. A stimulus coming in at *A* from the skin of the leg may travel to *B* in order to get action by the muscles of the arm to relieve the cause of the stimulus.

evolved to such an extent that in man it is composed of the brain, spinal cord, cranial nerves,* spinal nerves,*

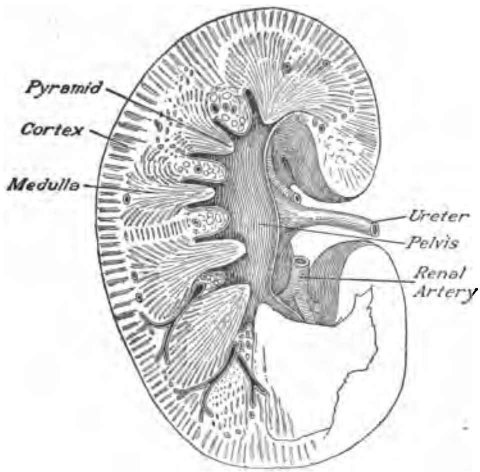


FIG. 38. — Section* of the kidney.

ganglia,* and peripheral nerves. The brain is the highly specialized center which controls and directs (Fig. 37). The rest of the structures exist for the purpose of carrying out the will of the brain. Certain acts go on, however, without the brain controlling them. Such are automatic and reflex. They represent functions that were carried on before the brain developed. They did not need the brain then; they do not need it now. Such acts are breathing and digesting food.

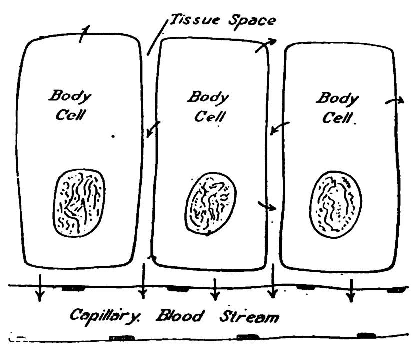


FIG. 39. — Waste from the cells going into blood stream.

Organs of the excretory system (Plate V). — As a result of chemical changes in the body, there are waste* substances which must be removed. These, together with the excess of water in the blood, are eliminated by the chief organs of the excretory system, the kidneys (Fig. 38). This system is very important in the mainte-

nance of body health, and the efficiency with which it works determines very largely the health of the whole body.

Plate V shows these organs in their position in the body. The large arteries, branching off from the main blood channel, carry the blood to the kidneys, and the veins carry it away after the waste has been removed. If the kidneys, through disease or other injury, become unable to remove this waste, the health of the body is impaired. Figs. 39–42 show the removal of waste from the cellular spaces and the subsequent elimination by skin, lungs, and kidneys.

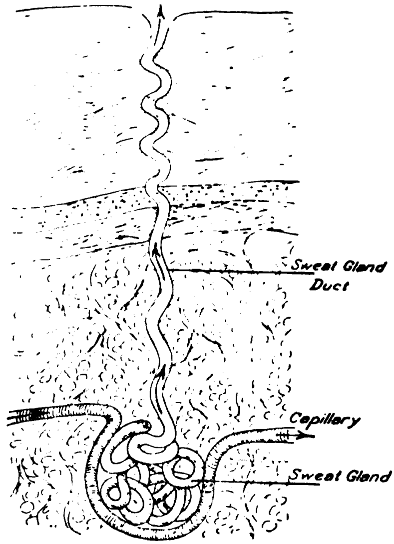


FIG. 40. — Sweat gland of skin removing waste from the blood.

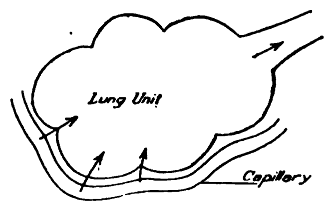


FIG. 41. — Waste from the blood eliminated by the lung.

The problem of keeping these organs strong and well is a complex one. All the factors that cause injury to the kidney cells are not known; but through study, experiment and close observation of

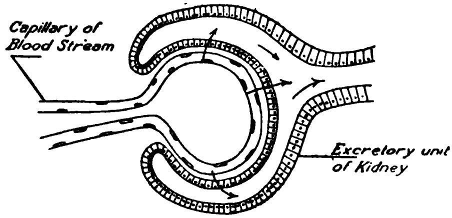


FIG. 42. — The elimination of waste by the kidney.

people's habits of living, some important directions for preserving the efficiency of the kidneys have been formulated.

It is generally agreed by physicians and hygienists that the habit of drinking plenty of pure water is valuable. For an adult, six to seven glasses a day are recommended. In a day's schedule, the drinking of water could be arranged in this way: one glass on rising, one at breakfast, one in the course of the morning, one at lunch, one in the middle of the afternoon, one at dinner, and one before retiring.

In addition, attention is to be given to the prevention of excessive work for the kidneys by reducing the amount of waste that these organs will have to eliminate. It will be learned later that the waste from animal food is largely removed by the kidneys. The restriction in meat eating would seem, therefore, to be another valuable method of protecting these organs.

The skin is, in part, an organ of excretion and so assists the kidneys. Keeping the skin healthy by frequent bathing and by wearing proper clothing is an important part of keeping the kidneys efficient. Chilling of the body, getting the feet wet, and sudden losses in body heat from various other causes, may be injurious to the kidneys.

Finally, it should be noted that the health of the excretory system cannot be maintained by patent medicines of the Kidney Remedy type. There are innumerable "cures" and "remedies" advertised in newspapers and magazines for the treatment of kidney disease. They are worthless, fraudulent, and exceedingly expensive. The restoration to health of these injured organs is usually a problem of adjustment of life, and the plan and program for that should be in the care of a skilled physician.

The reproductive system. — Simple one-celled animals, such as the amœba, reproduce by dividing into two parts. The entire body divides and two new individuals result from the one. In the higher mammals nature has formed a

CHARTS OF THE HUMAN BODY

SHOWING

DIFFERENT SECTIONS OF THE TRUNK AND HEAD
AND A SCHEMATIC REPRESENTATION OF
THE CIRCULATION

EXPLANATION OF PLATE I

Plate I shows the skeletal muscles on the ventral (front) part of the trunk. These muscles lie beneath the skin and are attached to the bones of the skeleton. The blood vessels and nerves which supply the muscles come from within the body and send their branches into the fibers of the muscles, giving nourishment and stimulation, and controlling elimination. The muscles of the trunk are more important than the muscles of the arm from the standpoint of health, because if the trunk muscles are not well developed, the heart, lungs, digestive organs, and nervous system will not be vigorous.

PLATE I

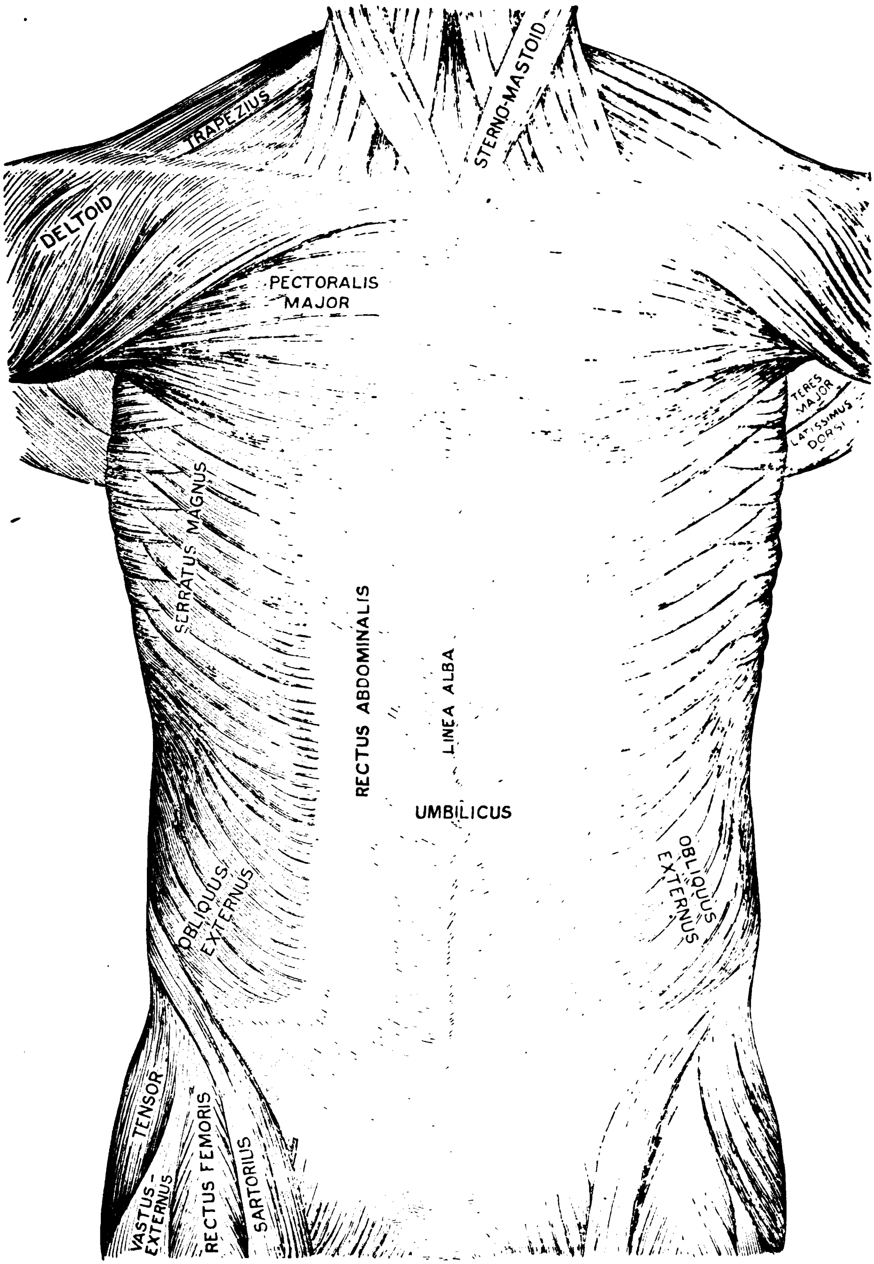
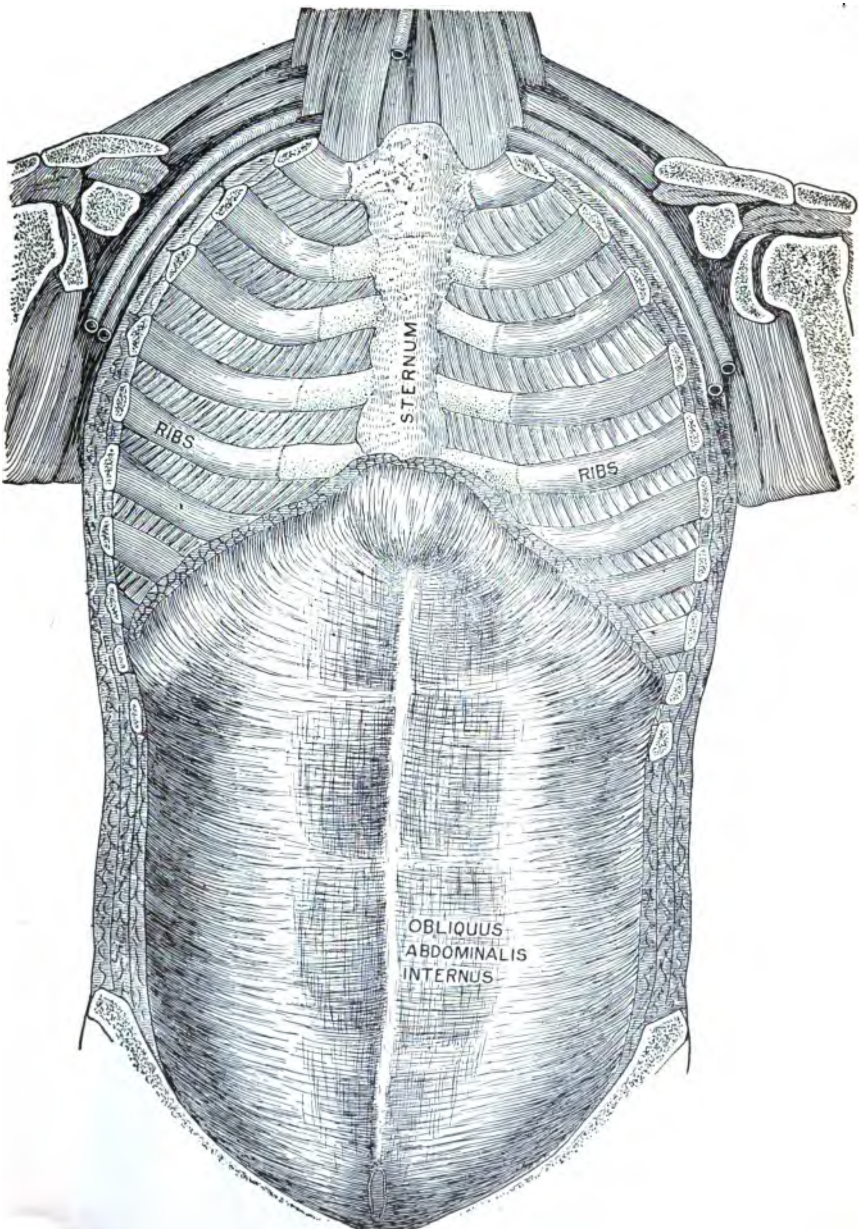

TRAPEZIUS
STERNO-MASTOID
DELTOID
PECTORALIS MAJOR
TERES MAJOR
LATISSIMUS DORSI
SERRATUS MAGNUS
RECTUS ABDOMINALIS
LINEA ALBA
UMBILICUS
OBLIQUUS EXTERNUS
OBLIQUUS EXTERNUS
TENSOR
VASTUS-EXTERNUS
RECTUS FEMORIS
SARTORIUS

PLATE II



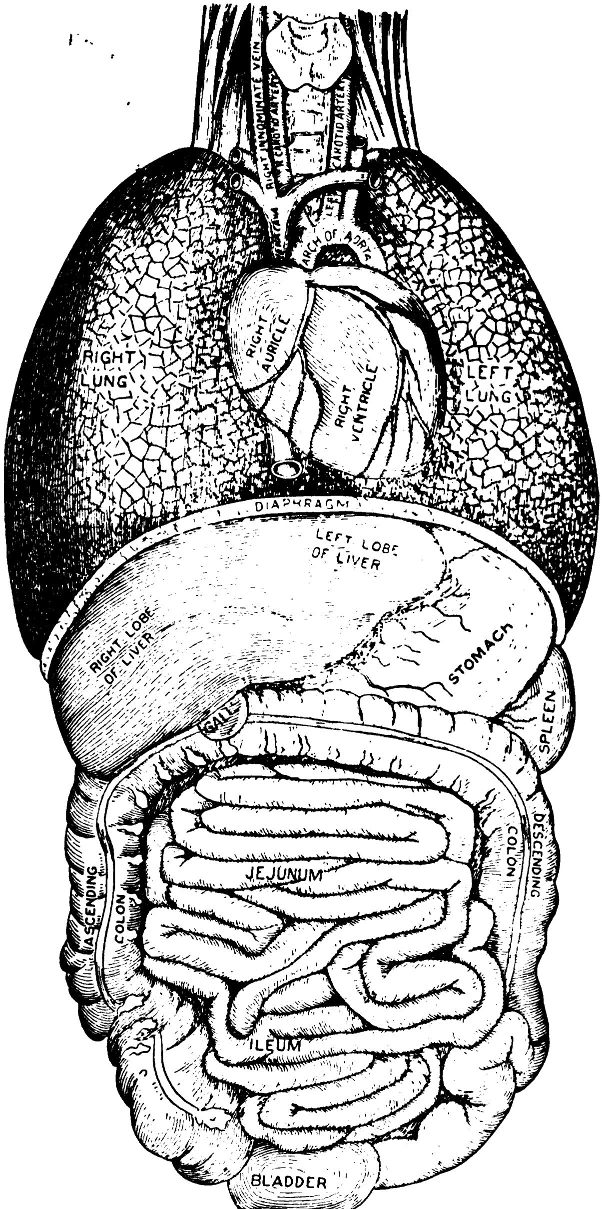
EXPLANATION OF PLATE II

This Plate presents the rear view of the front wall of the body. It shows the ribs which lie beneath the muscles of the chest illustrated in Plate I and the inner layer of tissue that makes up the structure of the abdominal wall. The organs shown in Plate III lie against the ribs and abdominal wall pictured here.

EXPLANATION OF PLATE III

This Plate shows the organs of the trunk as they appear after removing that part of the body indicated in Plates I and II. The diaphragm runs transversely across the body and separates the organs of the chest (heart and lungs) from the organs of the abdomen (stomach, liver, intestines, etc.). The diaphragm is a muscle and when it contracts it moves downward and helps to bring air into the lungs. Notice the situation of the liver and stomach. Increased action of the diaphragm following exercise massages these organs and improves their action. Breathing exercises alone are not as valuable as those that cause the respirations to increase in response to the needs of the body.

PLATE III

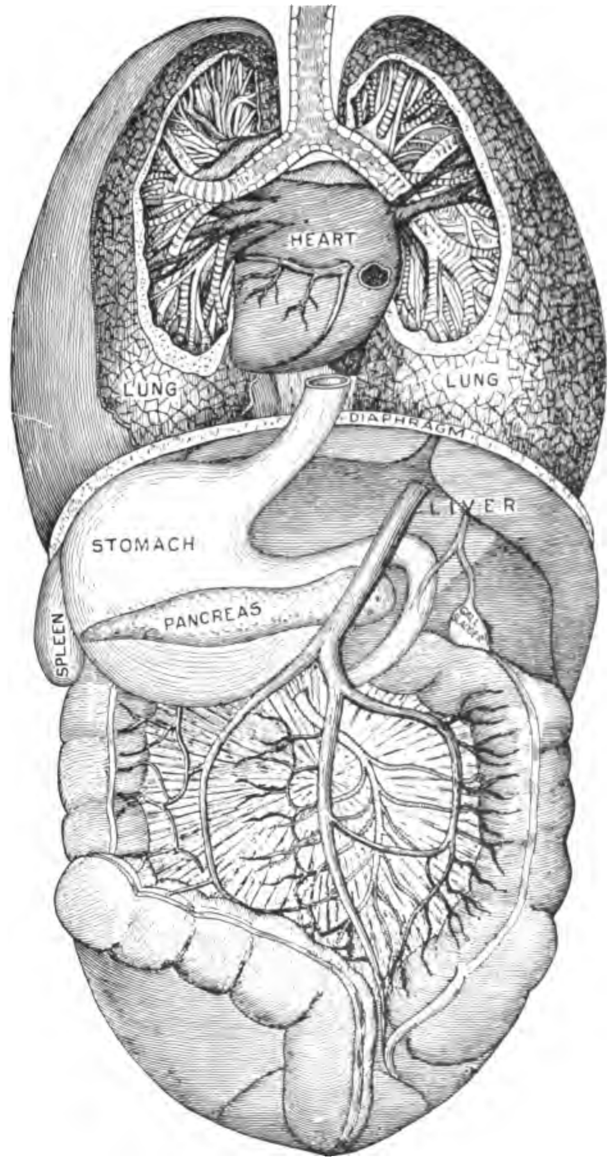


RIGHT INNOMINATE VEIN
CAROTID ARTERY
CAROTID ARTERY
ARCH OF AORTA
RIGHT AURICLE
RIGHT LUNG
RIGHT VENTRICLE
LEFT LUNG
DIAPHRAGM
LEFT LOBE OF LIVER
RIGHT LOBE OF LIVER
STOMACH
GALL
SPLEEN
COLON
DESCENDING
JEJUNUM
ASCENDING
COLON
ILEUM
BLADDER

EXPLANATION OF PLATE IV

This view shows the rear of those structures indicated in Plate III. Part of the lungs have been removed to show the way in which the blood vessels from the heart enter the lungs, and to show the tubes (bronchi) which carry air in and out of the lungs. In the abdominal part there are two organs that were not shown in Plate III. One is the pancreas, that lies behind the stomach, and the other is the gall bladder, that lies on the under surface of the liver. Notice the large blood vessels going to the intestines. If the muscular wall shown in Plate I is not held in place and well contracted these blood vessels will be stretched and will be less able to carry blood to the organs of the abdomen. It is important, therefore, always to stand erect so that the organs of the abdomen will receive the full supply of blood which they need.

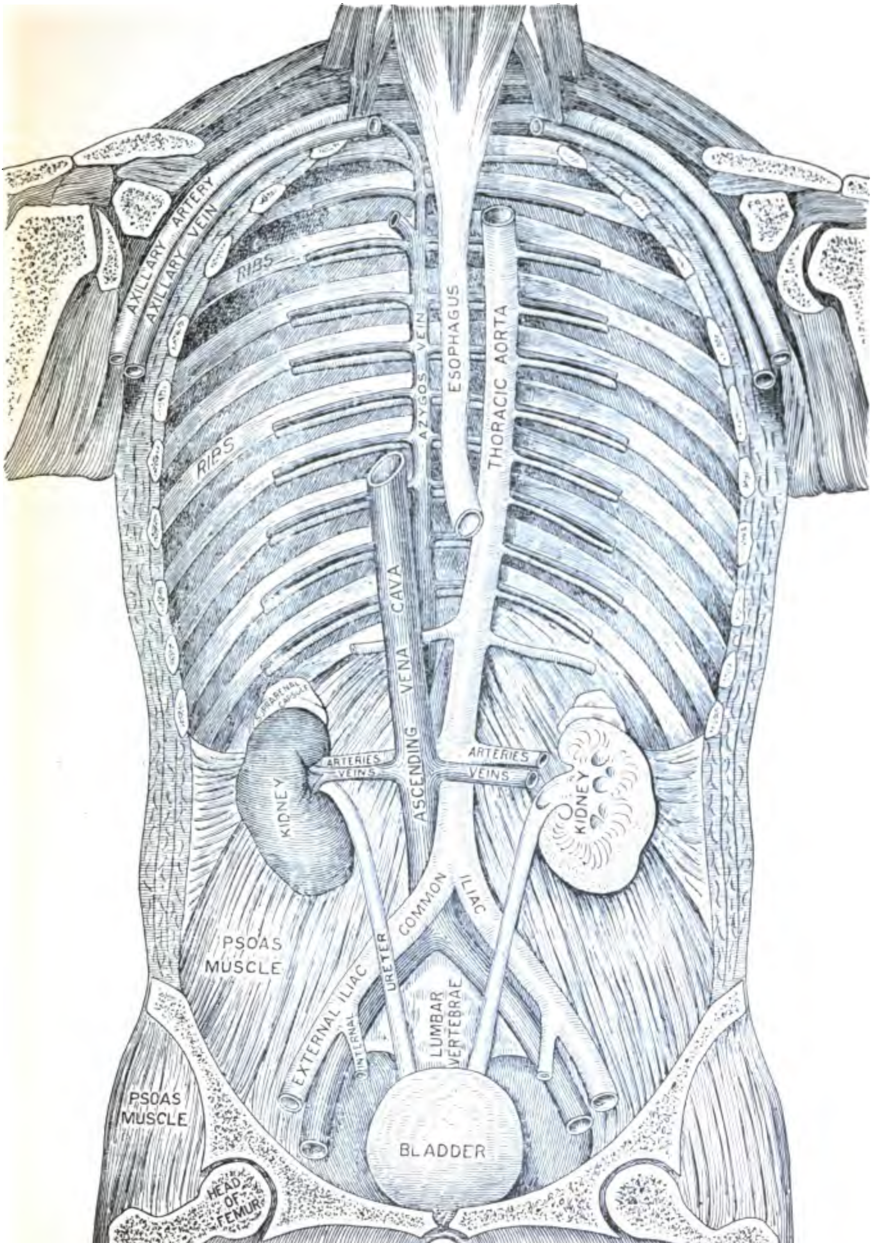
PLATE IV



EXPLANATION OF PLATE V

This Plate presents the front view of the back wall of the trunk with all the organs of the chest and abdomen removed except the kidneys and bladder. This view shows the esophagus, which empties into the stomach; the large blood vessels going to and from the heart. The kidneys are seen receiving blood from the renal artery and sending blood away in the renal vein. The kidneys take the impurities from the blood and remove the excess of water. The excretion is carried in tubes, marked ureter, to the bladder. All the organs are of importance in maintaining the health and strength of the body, and the excretory system is as important as if not more important than the others.

PLATE V


AXILLARY ARTERY
AXILLARY VEIN
RIBS
RIBS
AZYGOS VEIN
ESOPHAGUS
THORACIC AORTA
ASCENDING VENA CAVA
ARTERIES
VEINS
ARTERIES
VEINS
KIDNEY
KIDNEY
COMMON ILIAC
URETER
PSOAS MUSCLE
EXTERNAL ILIAC
INTERNAL
LUMBAR VERTEBRAE
PSOAS MUSCLE
BLADDER
HEAD OF FEMUR

EXPLANATION OF PLATE VI

This Plate shows structures inside the skull and face. It is a composite picture, being made up of several different sections. It shows the spinal cord with its connections with the cerebrum (brain); the eye and optic nerve; and nerves going from the brain to the teeth, the nose, and the muscles of the neck. It is to be noticed that the brain and nerves are well protected, the brain being covered by the bony skull and the nerves gaining protection from the bones of the face and soft parts. The bones protecting the spinal cord have been cut away in order to show this structure.

PLATE VI

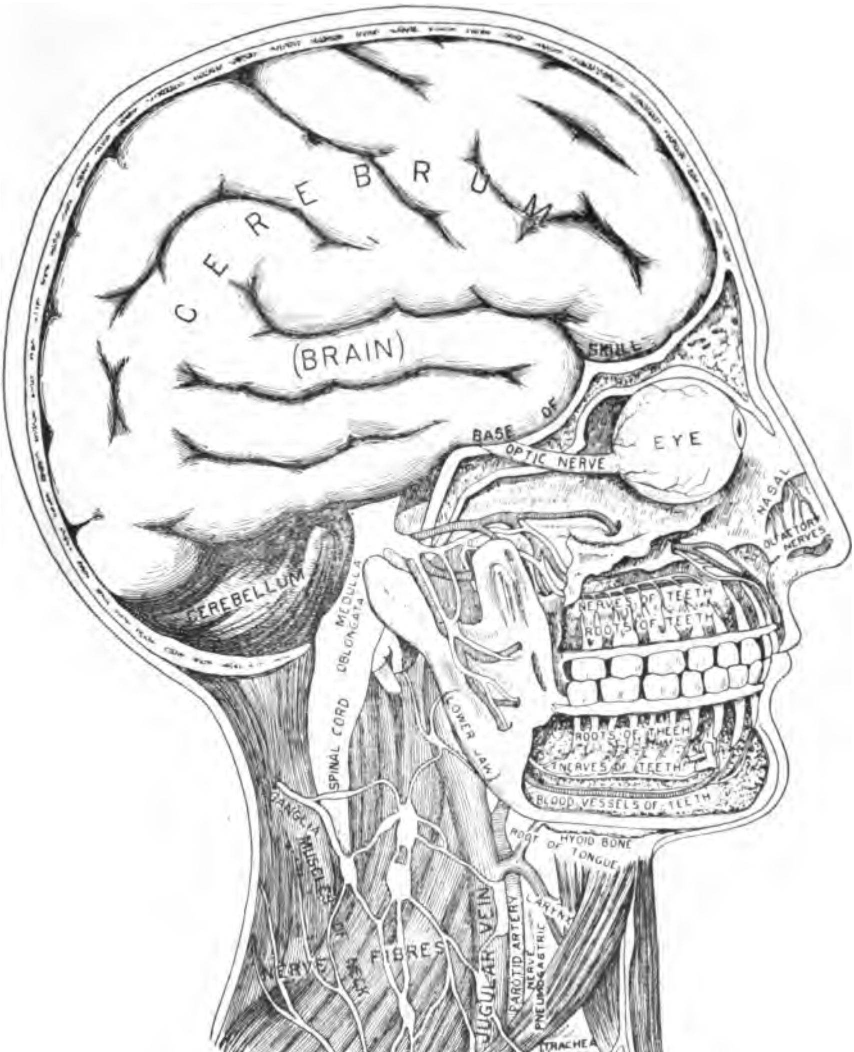
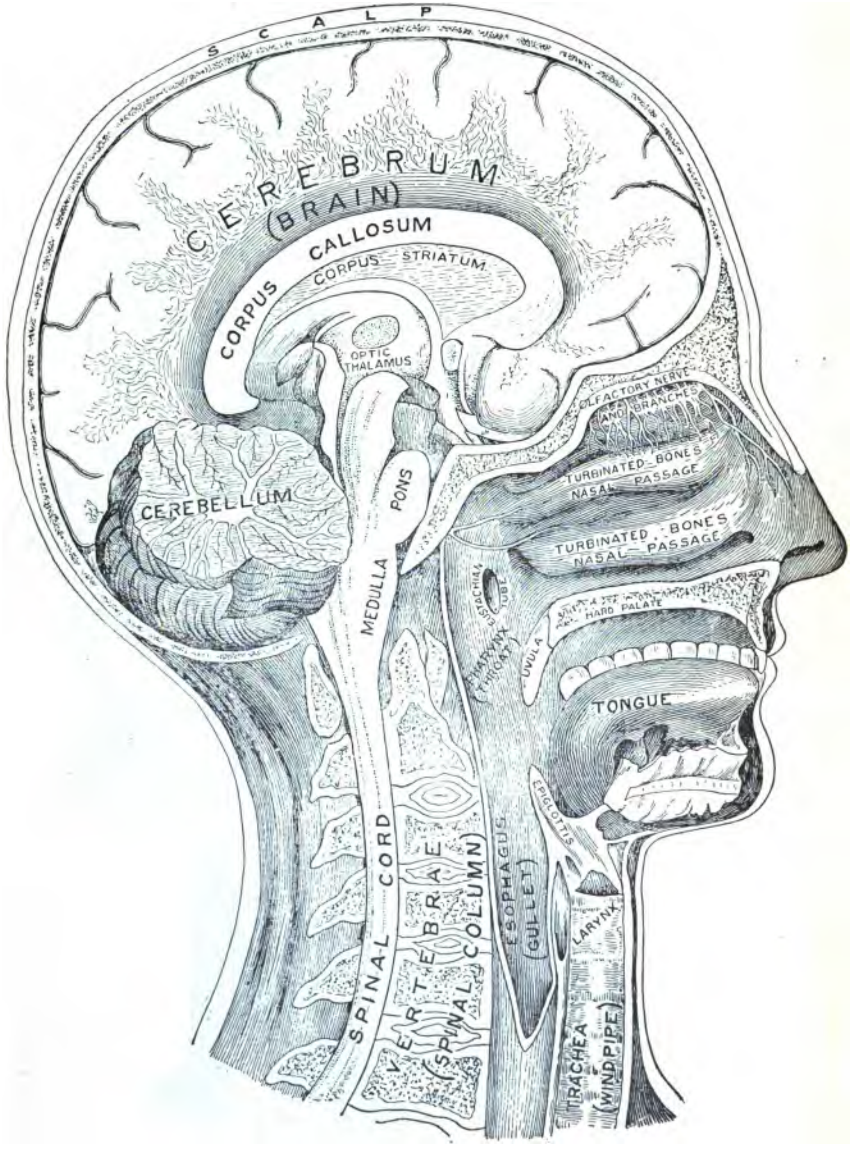

CEREBRUM
(BRAIN)
SKULL
BASE OF
OPTIC NERVE
EYE
NASAL
OLFACTORY NERVES
CEREBELLUM
MEDULLA OBLONGATA
NERVES OF TEETH
ROOTS OF TEETH
LOWER JAW
ROOTS OF TEETH
NERVES OF TEETH
BLOOD VESSELS OF TEETH
SPINAL CORD
GANGLIA
MUSCLES
ROOT OF
HYOID BONE
TONGUE
LARYNX
NERVE FIBRES OF NECK
JUGULAR VEIN
CAROTID ARTERY
PNEUMOGASTRIC NERVE
TRACHEA WINDPIPE

PLATE VII


SCALP
CEREBRUM
(BRAIN)
CORPUS CALLOSUM
CORPUS STRIATUM
OPTIC THALAMUS
OLFACTORY NERVE AND BRANCHES
CEREBELLUM
PONS
MEDULLA
TURBINATED BONES
NASAL PASSAGE
TURBINATED BONES
NASAL PASSAGE
EUSTACHIAN TUBE
HARD PALATE
PHARYNX (THROAT)
UVULA
TONGUE
EPIGLOTTIS
SPINAL CORD
VERTEBRAE
(SPINAL COLUMN)
ESOPHAGUS
(GULLET)
LARYNX
TRACHEA
(WINDPIPE)

EXPLANATION OF PLATE VII

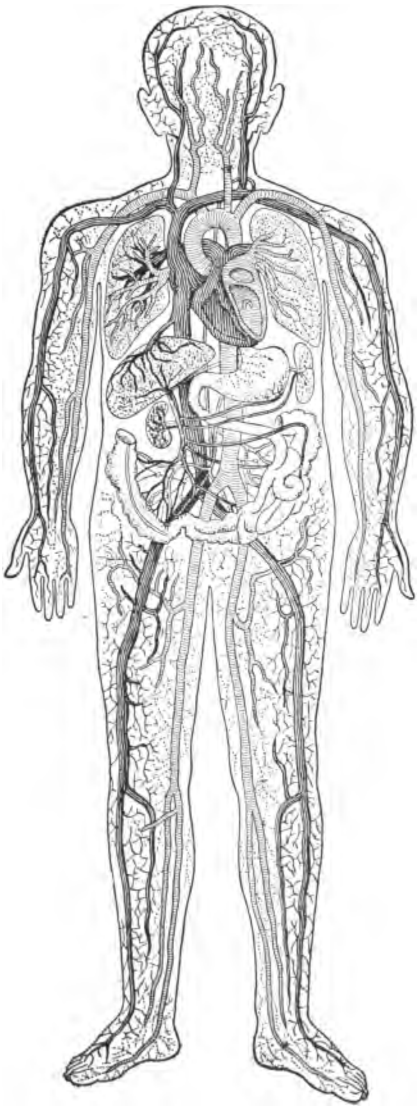
This view of the head is that which would be presented by looking at the surface of the sagittal section through the head. The opening from the mouth into the esophagus and the pathway from the nose to the lungs are shown. The spinal cord entering the base of the brain is clearly indicated and some of the internal structures of the brain are represented. The corpus callosum is composed of fibers connecting the two sides of the brain. The cerebellum is shown cut across; the pons lies in front of it. In the medulla are situated the vital centers of life — the respiratory, cardiac, and vaso-motor centers.

EXPLANATION OF PLATE VIII

[OVER]

This Plate represents the circulation of the blood. The blood flowing from the left side of the heart is represented in the arteries by a circular marking; that coming to the right side of the heart and from there to the lungs, in the veins by a straight line. This representation of veins and arteries indicates a difference in structure; it also suggests one very important fact in the circulation — the blood which the heart sends out to the cells of the body is not the same in composition as that which returns to the heart. The chief difference is a waste product of oxidation, carbon dioxide. Trace the blood from the left side of the heart to the head, hands, and feet by the arteries; trace the blood from the right side of the heart to the lungs; and trace the blood from the head, hands, and feet by the veins to the heart.

PLATE VIII



complex system of special organs to care for this important work of reproducing the species. Nature's laws here as elsewhere are helpful when understood. Ignorance of these laws results, frequently, in disease, in loss of health and happiness. Parents or the family physician are the logical persons to instruct children in these laws. It should be remembered that the proper care and functioning of this system determines not only the health and happiness of the individual, but also the health and prosperity of the race.

APPLIED ANATOMY

LABORATORY EXERCISES

1. To demonstrate the digestive organs.

Obtain from the body of a cat or rabbit the stomach and intestines. Tie off the two ends. Show the relations between stomach and intestines. Indicate the mesentery and show how the blood vessels coming to the intestines run in the mesentery supporting the tube.

2. To demonstrate the organs of respiration and circulation.

From the same source as in (1) obtain the lungs and heart. Place the specimen in water. Do the lungs float? Show the relation between lungs and heart.

3. To demonstrate organs of the nervous system.

Obtain from the butcher a fresh calf brain and also a section of the spinal cord of the hog or calf. Show how the spinal nerves come off from the cord and indicate the root of origin of the cranial nerves.

4. To demonstrate organs of the muscular system.

Obtain from the butcher the fore leg of a calf. Dissect out the tendinous attachment of the muscles and at the joint indicate the difference between the tendon and the ligament.

5. To demonstrate the organs of the excretory system.

Obtain from the butcher the kidneys from a calf and indicate for the class the arterial and venous blood supply. By a diagram show how the kidney removes waste from the body and emphasize the importance of water in the diet.

GLOSSARY

Abdomen. — The cavity lying between the diaphragm and pelvis and holding the viscera. The viscera is the plural term for

viscus. Viscus refers to the organs in the abdomen, such as the intestines and stomach.

Center. — Used here in connection with the nervous system, *i.e.*, nerve center. A group of nerve cells arranged in a circumscribed mass for the purpose of carrying on a particular function or coördination.

Cerebrum. — The upper and foremost part of the brain. It consists of two symmetrical halves, called hemispheres. In man and the higher animals the cerebrum is the chief bulk of the brain. It is supposed to be the seat of thought and will.

Cerebellum. — A part of the brain lying below and behind the cerebrum. It is much smaller than the cerebrum and is concerned with equilibrium and allied functions.

Comparative anatomy. — The study of the structure of different animals and man with reference to similarities and differences in structure and development of organs in different species.

Corpus callosum. — A great band of nerve fibers that runs transversely across the brain, connecting the two hemispheres. As compared with other parts of the brain, this band is very hard and it receives its name from being a " hard body."

Cranial nerves. — The nerves that come off from the brain. There are twelve pairs and comprise such nerves as the optic (to the eyes), the auditory (to the ears), the facial (to the face), and the vagus (to the heart).

Diaphragm. — A muscle situated between the cavity of the chest and the abdomen. It is the chief muscle of respiration. When it contracts it descends and causes air to rush into the lungs; when it relaxes it rises and forces the air out.

Esophagus. — A tube composed of muscle and membrane, about ten inches long. It serves to carry food and drink from the mouth to the stomach. It is sometimes called the gullet.

Evolution. — A term to denote the development of the complex individual from the single cell and to explain the way in which all development has occurred and the conditions modifying such development.

Gall bladder. — A muscular bag that lies on the under surface of the liver and holds the bile secreted by that organ.

Ganglion. — A group of nerve cells lying outside the spinal cord.

Intercostal. — One of a group of muscles attached between the ribs and concerned in respiration.

Larynx. — The upper part of the air tube. It contains the vocal cords.

Liver. — A large gland composed mainly of epithelium, situated in the upper part of the abdomen on the right side. It secretes a liquid called bile; it stores sugar in the form of glycogen; and it removes certain waste substances that come to it in the blood.

Medulla oblongata. — The extreme upper part of the spinal cord, forming the connecting structure between the cord and the brain. It is conelike, and about one inch long. It contains important nerve centers such as the respiratory center, the cardiac center, the vaso-motor center, etc.

Pancreas. — An organ of digestion concerned in the metabolism of fat, sugar, and protein.

Pons. — Usually called the Pons Varolii after the anatomist of Bologna, Constanza Varoli. It is a part which contains the fibers from the two hemispheres of the cerebellum. The corpus callosum was the connection between the two parts of the cerebrum; the pons is the connection between the two parts of the cerebellum.

Section. — A picture or view of a part or body that would be seen if it were cut by an intersecting plane. If the cut is made across, the section is transverse; if lengthwise, it is called a longitudinal section.

Spinal nerves. — Nerves that have an attachment with the spinal cord. They comprise nerves going to the cord and nerves coming away from the cord.

Stomach. — An enlargement of the alimentary tract that serves to hold food while it is being acted upon by digestive juices secreted by the stomach.

Trachea. — The tube connecting the lungs with the mouth and nose cavities.

Vaso-motor. — Refers to movement produced in the blood vessels. This movement may be constriction in which the lumen grows smaller; or it may be dilatation in which the lumen grows larger. Vaso comes from *vas*, meaning vessel. Constriction of the vessel is called vaso-constriction; dilatation of the vessel is called vaso-dilatation.

Waste. — The waste substances in the body result from the chemical changes that go on in the production of energy. Ashes represent the waste of combustion when wood and coal are burned. The waste of the cells of the body is represented by such substances as carbon dioxide, urea, uric acid, creatin, xanthin, etc.

CHAPTER V

THE SKELETON FRAMEWORK OF THE BODY

I. The Use of the Skeleton.
- For attachment of muscles
- For support and protection
- For movement

II. Parts of the Skeleton.
- The skull
- The vertebral column
- The thorax
- The shoulder girdle
- The arm
- The leg

III. The Structure of a Long Bone.

IV. The Composition of Bone.

V. Joints.
- Motion in movable joints

The use of the skeleton. — There are some animals, such as the slug and the jelly fish, that do not possess any hard part corresponding to a skeleton. Such an animal if it lives on land, lies flat on the ground, and moves slowly and with difficulty. Animal life in its lowest forms is characterized by a resemblance to plants; in fact, in the case of bacteria* it is not known whether they are plants or animals. Plants in both high and low forms are characterized by their immobility. Animals in their evolution from lower to higher forms have increased their power to move about. So far as movement on land is concerned, the feature that brought an increased range of movement was the bony skeleton.

Evolution is a slow and gradual process and the skeleton of man is the result of centuries of development.

For attachment of muscles. — The bones that form the skeleton of man (Fig. 43) make possible not only movement of the body itself but also of its parts. Muscles attached to two bones, on contracting and shortening, pull the two bones toward each other. If the bone at one attachment is held in a rigid way, the contraction will result in a movement of the other bone toward the fixed part. We say, therefore, that bones serve for the attachment of muscles and give support from which the muscles can pull.

For support and protection. — Bones also give support to the body. Man could not be an erect animal if there were not a rigid skeleton to support his organs and parts. In addition, the bones serve for protection, for even in man, so capable of self-protection, it is necessary to have the skeleton to protect some of the delicate organs. Some animals have developed for protection other means also. The scales of the fish, the quills of the porcupine, the heavy fur of arctic animals, serve to protect these animals from various forces in their separate environment.*

In man the bones that protect the vital organs are flat, as the breastbone and shoulder blade, the ribs, which protect the heart and lungs, and the skull bones, which protect the soft and delicate brain.

For movement. — Bones serve for the attachment of muscles, they give support and protection, and they increase the possibilities of movement of the parts of the body. The muscles by their shortening accomplish very simple and imperfect motions; by using the bones for support and as levers, this motion is changed in rate, direction, and place of application.

The long bones of the arms and legs, with the fingers and toes, have motion as their chief function. The ribs are flat but they are the longest bones in the body in proportion to their

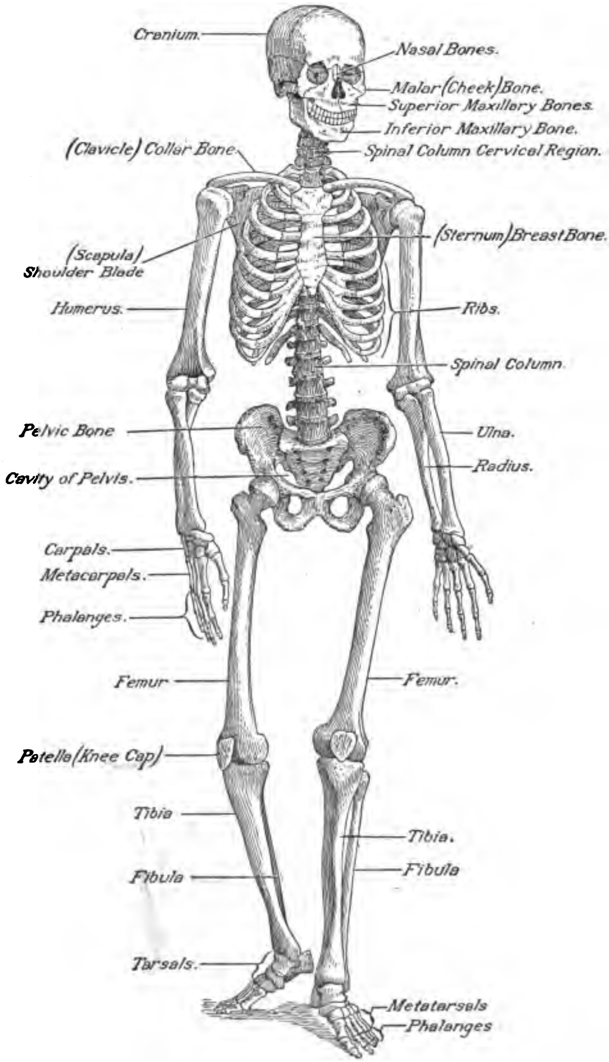


FIG. 43. — The skeleton.

size, and enable us to perform the important motions of breathing. Yet they are classed as flat bones, for they lack the round shaft and enlarged ends or heads which typical long bones have. Even the bones of the instep, palm, fingers, and toes, which are the smallest of the long bones, have the shaft and heads.

Many of the small, short bones are stronger than the long, slender bones, or the flat, thin ones. These bones are called irregular bones. They are not easily broken and their chief function is support. They are found in the spine, the ankle, the wrist, the knee, and the face. We should remember that the irregular bones also assist in the two other functions of protection and motion; also that the long bones and the flat bones are not confined to one function but participate in all three functions (Fig. 43).

Parts of the skeleton. — The central part of the skeleton called the vertebral or spinal column, forms a firm but flexible axis. The head rests upon the top of this column. The ribs are attached at its side to make the walls of the chest. The shoulder girdle rests upon the chest, and the hip girdle is attached to the base of the spinal column. These girdles connect the upper and lower limbs with the trunk. The bones of the head and trunk form the axial skeleton. The bones of the girdles and limbs are called the appended skeleton, since they are appended to the axial framework.

The skull (Fig. 44). — The skull is the cranium, or casket which contains the brain, and the facial bones. The arched form of the skull is the best shape for resisting blows and pressure. Its bones are so firm and hard that bullets sometimes glance from it, but the structures within the skull are so important and delicate that in war the head is protected by a metal helmet to resist shrapnel. The occipital bone curves under at the back of the neck to aid in forming the floor of the skull. It has two projections called condyles* (*knuckles*) situated just behind its junction with the sphenoid

(*wedgelike*) bone. The condyles fit into depressions (Fig. 45) in the uppermost vertebra; thus the head rests and rocks upon the spinal column. Grasp the neck with both hands so as to hold it motionless and stiff, and find whether the head rocks forward and backward, or sidewise. Between the condyles is a large opening through which the spinal cord goes from the brain.

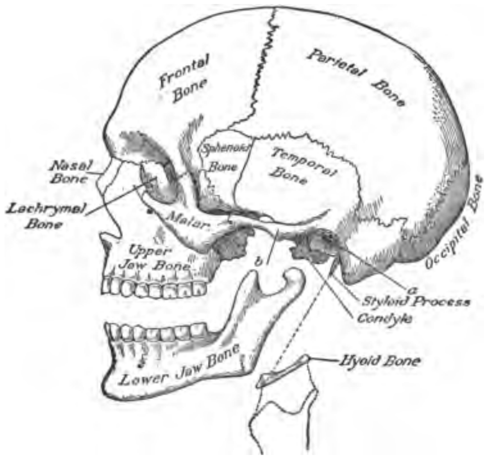


FIG. 44. — Side view of skull. The larger bones are named in the figure. The lower jaw is dropped down. Its socket in the skull is shown in front of the opening of the ear, *a*; *b*, process of temporal passing to malar, or cheek bone. Locate one of the condyles or projections which rest in sockets on the highest vertebra; the hyoid bone, not joined to any other bone, except by muscles; opening of ear and styloid process. A small part of the sphenoid bone is shown; the main part is at base of skull. The eight cranial bones are:

One Frontal (forehead)
One Occipital (back and floor)
Two Parietal (sides and roof)
One Sphenoid (central floor)
Two Temporal (sides)
One Ethmoid (front floor)

The vertebral column.—The spinal column consists in the adult of twenty-six bones (Fig. 45). Twenty-four of these bones have a similar shape, and each is called a vertebra (Latin, *that which turns*). The other two have the names of sacrum and coccyx. The first seven vertebræ are in the neck and are called cervical (*of the neck*). The next twelve are those to which the ribs are attached and are called thoracic or dorsal (*of the back*). The next five vertebræ are in the loins or lumbar region and are

called lumbar (*of the loins*). They arè the largest of the vertebræ. The lowest lumbar vertebra rests upon the sacrum (*sacred*, because this bone of lower animals was once used in sacrifice). In infancy the sacrum consists of five vertebræ; these begin uniting at two years of age and complete the union at twenty years. The coccyx (*cuckoo*, from its resemblance to the bill of a cuckoo), or last bone of the column, is that part of the skeleton which in the lower animals forms the tail. In infancy it consists of four small bones which later unite into one. The coccyx is of little use, but the sacrum is a highly important bone, since to its sides are attached the bones of the pelvic arch, by which the weight of the body is transmitted to the legs.

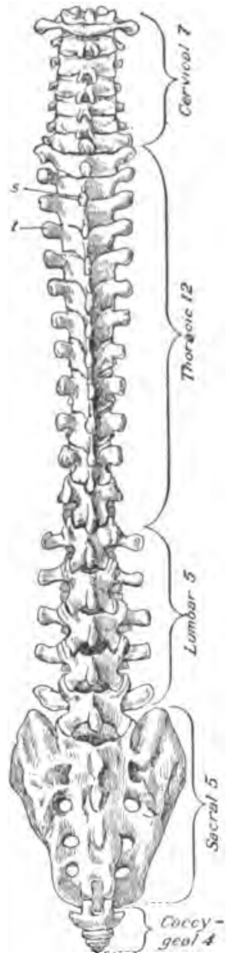


FIG. 45. — Spinal column (seen from behind). *s*, spinous process; *t*, transverse process. Find the 7 cervical, 12 thoracic, 5 lumbar vertebræ. Do the sacrum and coccyx show evidence of having been divided in early growth?

Vertebræ. — The different vertebræ all conform to a general plan of structure. On examination they show a large massive central part (the body), and leading from this part and running posteriorly (backward) are two processes of bone, the pedicles (Fig. 46, *A*). The pedicles are continuous with two other parts, the laminæ, and with them form the neural arch. Where pedicles and laminæ join there runs

off horizontally to each side a process, the transverse process. The laminæ at their junction behind meet the spinal process, which points directly backward.

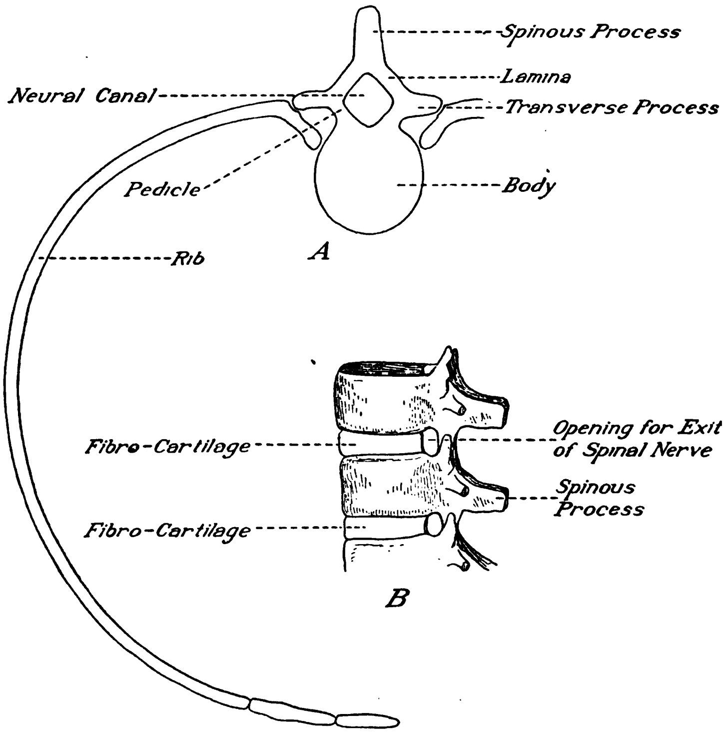


FIG. 46. — *A*, plan of a typical vertebra showing rib attachment; *B*, side view of several vertebræ showing inter-vertebral fibro-cartilage and openings for spinal nerves.

The arches formed by the pedicles and laminæ serve admirably for protection to the highly specialized spinal cord (part of the nervous system). The processes are well adapted by their roughened surfaces for the attachment of muscles and ligaments. Strictly speaking, however, the rough places on the bones are caused by the pull exerted by

the muscles at the point of attachment. Between the bodies of the vertebræ are elastic cushions (Fig. 46, *B*) called fibro-cartilages. These pads are of importance in preventing jar to the spine, and they assist greatly in all movements of the spine. It will be seen, therefore, that the spine is constructed to support the head, to keep the trunk erect, to protect the spinal cord of the nervous system (Fig. 47), and to allow motion of the spine. This last function is provided for by the separate vertebræ, which means, of course, that each vertebra need move only a little to get a resulting large movement. The whole is equal to the sum of its parts.

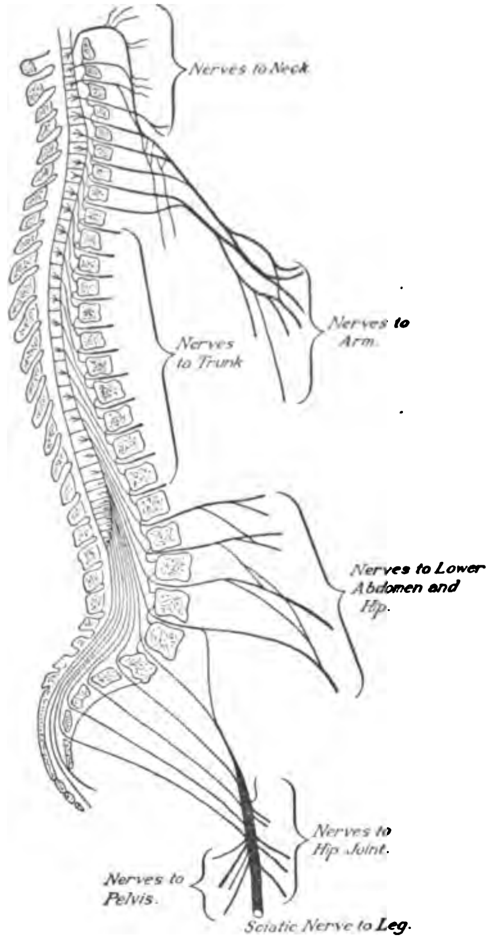


FIG. 47. — Spinal cord in the vertebral column, showing segments of cord and emergence of nerves going to arms, trunk, and legs. (After Dejerine and Thomas in Starr.)

Curves of the Spine. — When the vertebral column is viewed from the side (Fig. 47), it shows four curves. The cervical curve starts with the first vertebra and extends to the second thoracic vertebra. It is convex forward. The thoracic curve begins with the second thoracic and ends with the twelfth thoracic. This curve is concave forward. The lumbar curve begins with the twelfth thoracic and ends at the junction of sacrum and fifth dorsal. It is convex forward. The sacral curve completes the picture with a deep concavity forward. Figure 48 represents the curvature in these sections. The degree represents the number of degrees in a segment of a circle of which this curve is the arc. The figures given in inches represent the radius of each segment.

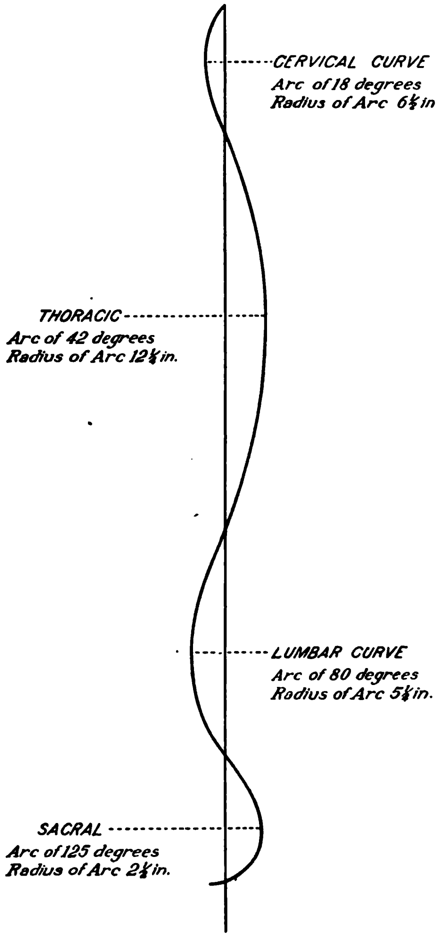


FIG. 48. — Normal curves of the spine. Notice that the spine is faced in the opposite direction from the one shown in Fig. 47. These curves are normal. They should not be changed because the body is injured.

The thoracic and sacral curves are called primary curves because they are present when the child is born. The cervical and lumbar curves are compensatory or secondary, because they develop after birth by the effort the child makes to hold up its head and to walk erect. Now, the important thing for us to remember is that nature provides us with a backbone that has curves. These curves are normal and they should be maintained. Some boys and girls stoop over so much that they increase the thoracic curve. This destroys their good appearance and also interferes with the development of their lungs. Girls by improper modes of dressing often increase the lumbar curve too much. This results in a weak and painful back.

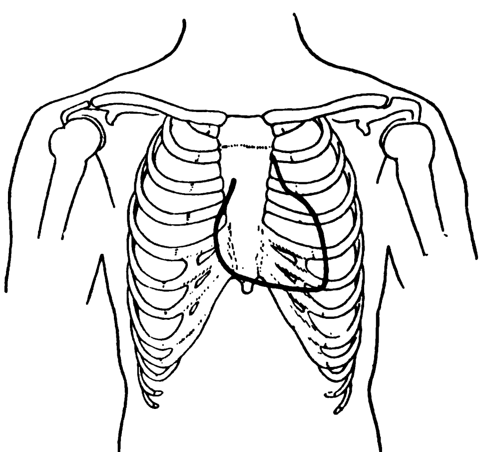


Fig. 49. — Front view of thorax and shoulder girdle showing projection of heart on chest wall.

The thorax. — The thorax, or chest, is formed in the rear by the twelve thoracic vertebræ; in front, somewhat parallel to the spinal column, but approaching it above, is the sternum, or breastbone (Fig. 49).

Twelve ribs curve around each side. Each rib joins one of the thoracic vertebræ behind. The first seven pairs directly join the sternum in front by means of short cartilages, and are called true ribs. The next three pairs, called false ribs, do not reach the sternum, but each rib unites to the rib above by a long cartilage. The last two pairs are

called floating ribs, since the front ends are not attached to a bone either directly, like the true ribs, or indirectly, like the false ribs, but rest in the muscular walls of the waist (Fig. 50).

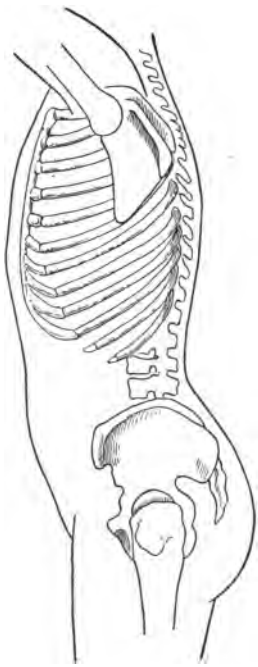


FIG. 50. — Side view of thorax, spine, and pelvis.

The shoulder girdle. — The arms are attached to the trunk by the shoulder girdle. This consists of four bones, two on each side, scapulæ or shoulder blades, and the clavicles, or collar bones. Each shoulder is composed of a clavicle (*key*, from its resemblance to the ancient key) and a scapula (Fig. 51). The scapula (*trowel*) occupies the rear part of the shoulder. It is a large flat bone of triangular shape and bears in the end at the angle of the shoulder a shallow socket into which is fitted the end of the upper bone of the arm. The clavicle is a slender bone, round and slightly curved, which occupies the front of the shoulder, and is joined at one end to the scapula and at the other to the sternum. The clavicles can be felt at the right and left of the base of the neck.

The arm. — The arm consists of the upper arm, forearm, wrist, and hand (Fig. 51). The upper arm extends to the elbow and has only one bone, the humerus. From the elbow to the wrist is the forearm, formed of two bones. arranged parallel to each other; the ulna is on the inner side, the side corresponding to the little finger; the radius occupies the outer side, the same side as the thumb. At the lower end of each, a bump may be felt, the bump on the ulna being larger. The wrist is called the carpus,* and is

composed of eight small bones arranged parallel in two rows, four in each row, running across the wrist. Next follows

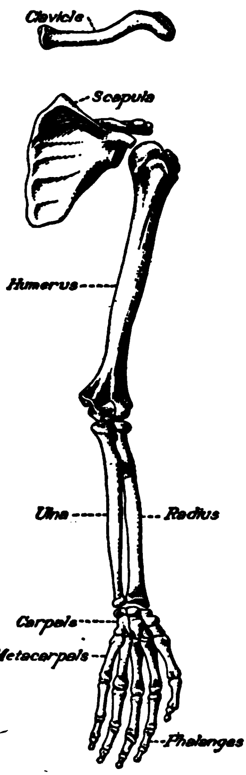


FIG. 51. — The arm and the shoulder. Seen from the rear. Why do the fingers seem so long?

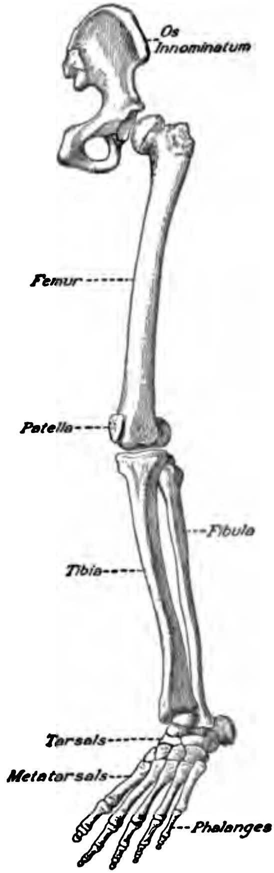


FIG. 52. — Bones of the hip and leg. Front view.

the metacarpus* (*beyond the carpus*) (Fig. 51), or the bones in the palm of the hand. The palm is composed of five long bones, each serving to support a finger or thumb. Each

finger is composed of three small bones called phalanges (*rows of soldiers*); the thumb has only two. The thumb is more movable than the fingers, and can be opposed to each of them.

The leg. — The skeleton of a lower limb has a striking resemblance to that of an upper limb (Fig. 52). The hip

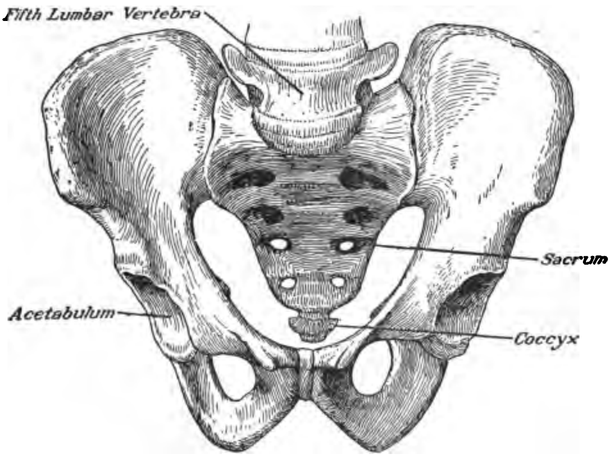


FIG. 53. — The pelvis.

girdle, corresponding to the shoulder girdle, forms the hip. The hip bones, or innominate (*nameless*, because they do not resemble anything) bones, are large, flat, and somewhat semicircular in shape. They meet in front (Fig. 53), but behind they join the portion of the spinal column called the sacrum, which separates them and forms, as it were, the keystone of the arch. Thus is formed a large band of bone inclosing a basin-shaped space, called the pelvis (*basin*), which contains the bladder, rectum,* and generative organs. There is a deep socket at the side in each innominate bone. This socket is occupied by the round head found on the upper end of the thigh bone, or femur. The femur is the largest and longest bone in the body (Figs. 54, 55).

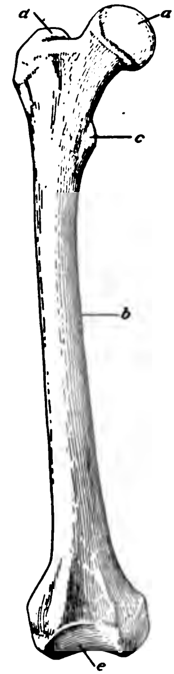


FIG. 54. — Front view of femur. *a*, smooth head of bone for articulating with hip bone; *b*, shaft; *c* and *d*, rough processes to which muscles are attached; *e*, smooth surface which articulates with tibia.

The leg below the knee, like the forearm, is composed of two parallel bones. They are unequal in size, like the radius and ulna. One, called the tibia, is much larger than the other, the fibula (Fig. 52). The latter bone is merely a brace to the large tibia, which forms the joints with the femur above and the foot below. There is a bony disk embedded in the great tendon over the knee, forming a protection to the knee joint; this is called the patella, or knee-pan. In which direction can you move the patella to and fro with the hand, when the leg is straight and the heel resting upon the floor?

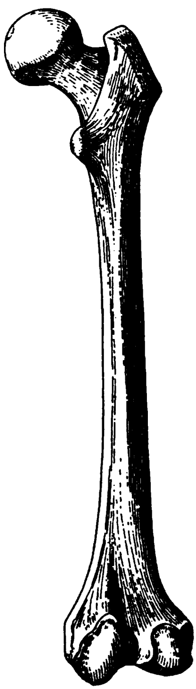


FIG. 55. — Femur (seen from behind).

Like the hand, the foot consists of three parts. The tarsus,* or ankle, is formed of seven bones, although the carpus has eight. The metatarsus,* like the metacarpus, is composed of five bones, arranged parallel to one another, which serve for the base of the toes. The toes have the same number of bones as the fingers, and have the same name, the phalanges.

The Structure and Hygiene of the Foot. — It is important to understand what the human foot is like, because abuse of

the foot is so common and the value of strong, sound feet is so great. The foot must support the weight of the body and in addition must serve to transfer the weight of the body from the heel to the toe in walking.

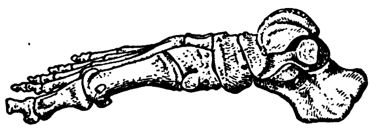


FIG. 56. — Skeleton of foot. If the child never goes barefooted, the arch is likely to become flattened instead of high.

1. *The bones are arranged to form an arch.* In the first place, the bones of the foot are arranged to form an arch extending from the toes to the heel (Fig. 56). This arch is low on the outer side of the foot and here the tissues covering the bones are in contact with the ground (Fig. 57). On the inner side, however, that arch is high and is held in place by ligaments on its under surface, and by small muscles (Fig. 58) attached to the bones of the foot, and by the tendons from the calf muscles which pass under this part of the foot on the way to the toes. In addition, the heel bone (os calcis) is placed more to the outer side of the foot. As regards the use of the foot, these anatomic facts mean that the weight of the body can be carried on the outer side of the foot to the best advantage. We should use the body in conformity with the laws of its construction. In this way we shall be more efficient. In walking, therefore, the weight should fall on the outer side of the foot (Fig. 57).

FIG. 57. — The track made by a natural foot. Make a test by wetting your foot and noticing the track made upon the floor.

2. *The muscles help to support the arch and the muscles must be used correctly.* In the second place, the muscles on the under surface of the foot (Fig. 58) must be kept strong and the muscles of the

calf, going to the toes, must be exercised. It is important, therefore, to walk with the feet parallel. This will more readily bring the weight on the outer side and in addition will allow better action of the foot muscles. If the feet are turned outward in walking (Fig. 59), the weight of the body will be transferred to the inner side of the foot just over the arch instead of passing forward over the toes (Fig. 60). The feet should not be turned inward, "pigeon-toe." The parallel position only is correct.

3. *Shoes must not distort the bony arrangement of the foot.* Shoes must not cramp the toes or press the toes outward. This occurs in pointed shoes and prevents the proper action of the foot muscles (Fig. 61).

4. *Shoes must not throw strain upon the foot.* If the foot is to remain useful and efficient, the arch must not be subjected to a change in position of the bones of the foot. High heels throw the bones of the arch out of position and prevent proper foot action (Fig. 62). Women who wear high heeled shoes are as barbarous in this respect as the Chinese women who bound the feet.

FIG. 58. — Sole of foot. Showing some of the muscles and tendons that bend the toes and support the arch.

The structure of a long bone. — If a long bone is sawed through lengthwise (Fig. 63), it will be observed that there is a central cavity containing yellow marrow.* (What cut of steak has a marrow bone?) We should observe also that the portions inclosing this cavity are of a dense solid structure, but that the bone is spongy near the ends, enlarged for forming the joints. The cavities in this spongy portion contain red marrow. A long bone is hollow. A given weight of material has more

strength in the form of a hollow cylinder than in the form of a solid rod. (Does this imply that a hollow cylinder is as strong as a solid one of the same size?)

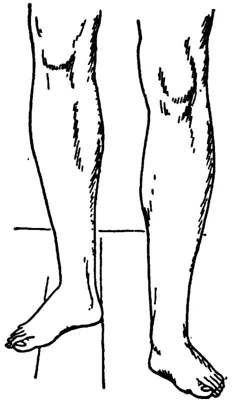


Fig. 59.—Feet should not be thrown out in this manner while walking.

The composition of bone.—Bone is covered with periosteum. This is the name given to the close clinging fibrous covering of the bone, composed of connective tissue and blood vessels. If we remove the periosteum from the surface, the red marrow from the pores, and the yellow marrow from the larger cavity, we have remaining the true bony substance. Yet even this is not one substance, but consists of mineral matter and animal matter in the proportion of two parts of the former to one of the latter. The animal matter is gelatin,* like the substance composing the white fibrous part of connective tissue. The mineral matter is chiefly phosphate of lime and carbonate of lime.

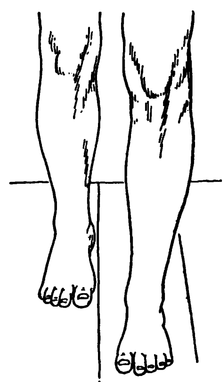


Fig. 60. — In walking the feet should be held parallel to each other. The weight should be placed on the outer borders of feet.

The mineral matter may be removed by soaking the bone for several days in strong vinegar or in dilute muriatic acid. The bone is then flexible but tough. If a slender bone, such as a hog's rib, has been used, it can be tied in a knot; after the acid has been washed off, it may be preserved in dilute alcohol as a curiosity. The animal matter may be removed by holding the bone on a shovel in the fire for a sufficient length of time. The mineral part remaining is very light and brittle, and weighs much less than the

PLATE IX. — X-ray of ankle, showing tarsus and lower end of tibia and fibula. Notice the bony arch.

original bone, the form of which it still preserves.

Joints. — The meeting of the ends of two bones makes a joint and this joint is held together by bands of connective tissue, called ligaments. Ligaments are composed of white fibrous tissue. Are they tough? Are they elastic or non-elastic? The way the bones are placed in the body to allow movement is shown in the X-ray picture (Plate IX). The shadow shows the outline of the ankle with the bones of the tarsus and the lower end of the tibia and fibula. The ligaments holding the bones to form the ankle joint do not show in an X-ray. This picture indicates how the bones are kept together and yet are free to move one upon the other.

FIG. 61. — The track made by a foot in which the natural arch has been partly broken down by tight shoes. If the arch breaks down entirely the foot is called flat foot.

Now all joints are not alike in the movement they allow. Some have very little motion; others move freely and over quite a range. The bones forming the skull have practically no motion in adult life and they are called fixed joints. They are remarkable in that the bones fit into each other by toothed edges, forming irregular lines, known as sutures. Other joints which we shall study have a free type of movement.

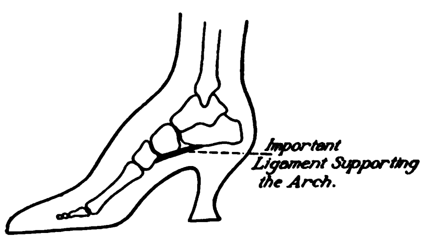


FIG. 62. — After wearing high heels the small bones of the foot are adjusted to a certain position. If a sudden change is made in height of heel, pain and disability follow. Pain in the knees and hips follows wearing high heels.

Let us take the knee joint, for example. The two bones which join are the femur and the tibia. They present to each other an enlargement, or head, which serves to increase the strength of the joint and increase the surfaces applied to each other. The two heads instead of being formed altogether of rigid bone are covered by cartilage, which by its elasticity and smoothness provides for the gliding of one bone upon the other. Strong fibrous bands called ligaments bind together the ends of the two bones. Surrounding the ends of the bones, like a collar, is found a ligament (the capsular ligament) inclosing the space of the joint in a closed sac. This closed sac is called the capsule. A thin membranous sac, called the synovial membrane, lines the capsule. It secretes a slimy fluid which resembles the white of an egg and is called the synovial fluid. This lubricates the joint, and is deposited continually, but only so fast as used up in exercise. As the sac has no opening, air is excluded, and atmospheric pressure aids in holding the bones in place. The hip joint (Fig. 64) and other joints have the same parts as the knee joint. It is rarely that two bones put together so perfectly are forced from their natural places. When this happens it is called a dislocation.

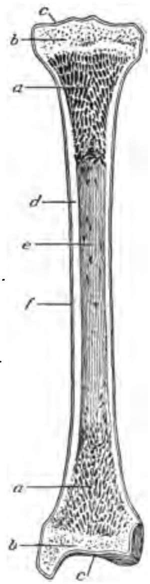


FIG. 63. — Shin-bone (tibia) sawed in two along its length. *a*, struts and stays of *b*, spongy bone supporting *c*, the upper and lower articular surfaces; *d*, compact bone forming the shaft; *e*, marrow cavity; *f*, periosteum.

Motion in movable joints. — Not all movable joints can be moved in a similar way. We can move the knee joint in two directions, forward and backward. The shoulder

joint is capable of more and wider movements. There are four varieties of movement in the joints of the body.

1. Gliding Motion. This is the simplest kind of movement. It is the rubbing of one surface on another and it is small in extent. Examples of this movement are found in the carpal and tarsal bones of the hand and foot.

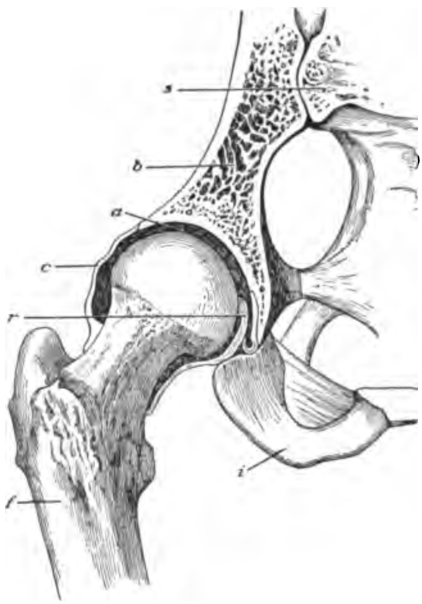


FIG. 64. — The right hip joint. The hip bone sawed through so as to show the cup of the joint. *a*, head of femur in acetabulum; *b*, ilium bone of pelvis; *c*, capsular ligament; *f*, femur; *i*, ischium bone of pelvis; *r*, round ligament of hip joint; *s*, sacrum.

2. Angular Motion. This type of motion occurs in only one plane. It is seen in what is called a hinge joint. Does a door swing in one plane? The human body has four varieties of angular movement, two in the forward and backward direction (the antero-posterior* plane of the body) and two in a sideward direction (movement from an antero-posterior plane of the body) (Fig. 65).

(*a*) *Flexion* in a joint is always in an antero-posterior plane of the body. The angle formed by the parts grows smaller during the movement. When the body bends forward, flexion occurs. Show flexion of the head, the fingers, the knee joint, the ankle joint.

(*b*) *Extension* in a joint is always in an antero-posterior plane and the angle becomes greater. The fingers are ex-

tended when they are stretched out straight. Show flexion and extension of the hip joint.

(*c*) *Abduction* is movement outward from an antero-posterior plane of the body and the angle increases in size.

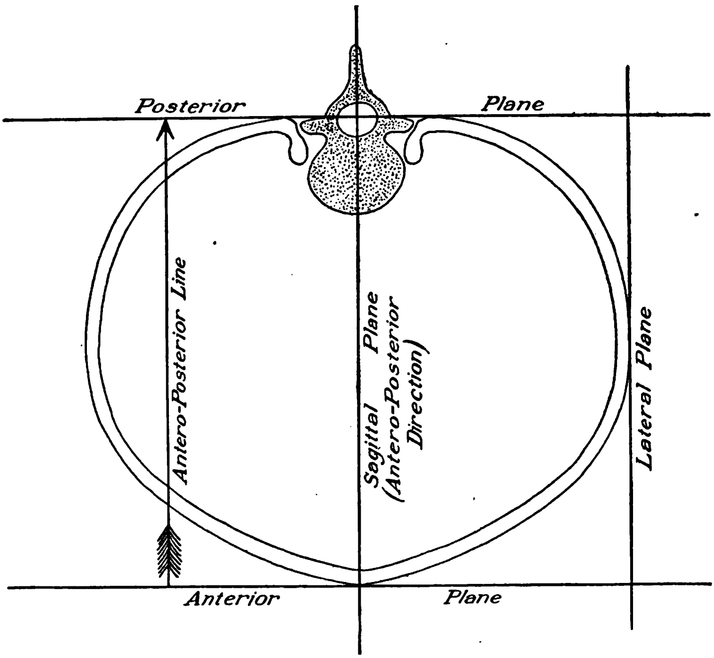


Fig. 65. — Diagram of a cross section of trunk showing planes and directions.

Raise the arm directly to the side. This is abduction of the arm. What is abduction of the head? Of the leg?

(*d*) *Adduction* is movement toward an antero-posterior plane of the body, and the angle between the parts decreases in size. Show adduction of the leg.

3. Circumduction. This movement is a combination of flexion, extension, abduction, and adduction. The end of the

moving part describes a circle and the part itself describes the sides of a cone (Fig. 66). Show circumduction of the arm.

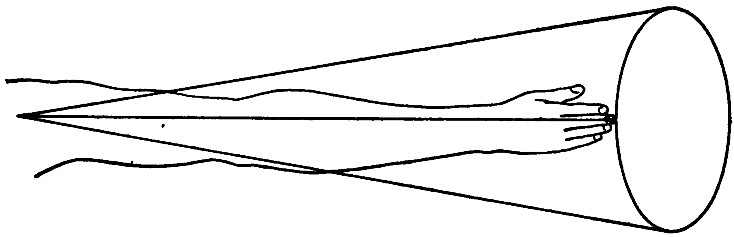


Fig. 66. — Circumduction — the extremity (hand) describes a circle and the part describes the sides of a cone.

4. Rotation. In this movement, the moving part turns around its own axis. Show rotation of the head. Show circumduction of the head.

GLOSSARY

Antero-posterior. — A compound word made up of anterior and posterior to denote a direction or plane passing from the anterior (front) part of the body to the posterior (back). If the anterior plane is a plane parallel to the front of the body and the posterior to the back of the body then it follows that there are innumerable antero-posterior planes and they will all be perpendicular to the anterior and posterior planes.

Bacterium. — The plural form is bacteria. They are small cells, spherical, rod-shaped, or spiral in form. Some are capable of causing disease in the body, but most of them are harmless. They are widespread in nature.

Carpus. — The eight small bones which form the wrist.

Condyle. — An enlarged and prominent part of a bone.

Environment. — All the external surroundings of an organism. The air, climate, food, work, play, housing, clothes, etc., make up the environment.

Gelatin. — A hard, transparent, tasteless substance obtained from animal tissue such as skin, hoof, and horns. It dissolves readily in hot water.

Marrow. — A soft, vascular tissue found in the cavities of bones. It contains fat and many cells of the blood.

Metacarpus. — That part of the hand between the wrist and fingers. It comprises five bones.

Metatarsus. — That part of the foot between the ankle and the toes. It comprises five bones.

Rectum. — The lower part of the colon. It is made of muscle and mucous membrane and is richly supplied with nerves.

Tarsus. — The seven small bones which form the ankle.

CHAPTER VI

HYGIENE OF THE SKELETON

I. The Nourishment of Bones.
II. Broken Bones.
III. Dislocations and Sprains.
IV. Weak Feet.
  Foot exercises
  Characteristics of a good shoe
V. Deformities of the Spinal Column.
  Lateral curvature of the spine
  Posterior curvature of the spine
VI. Posture.
  Sitting
  Lying down
  Standing
  Walking
VII. Essential Facts in the Growth and Development of Bones.

The nourishment of the bones. — If a limb be disused because of paralysis* or long sickness, the bones, as well as the soft parts, lose in strength and weight. This shows that the more vigorous circulation which comes with exercise helps to repair the osseous tissue. The blood vessels that supply the bones enter from the inner side of the periosteum. We thus see why the bone shrinks away if the periosteum is removed, and why the surgeon* is careful to leave as much of the periosteum as possible in the case of bones splintered by accidents.

The animal matter of bones is most abundant in childhood, and a child's bones will bend before they break. If broken, they heal rapidly. The animal matter is less abundant in

the aged, therefore, the bones are brittle and more easily broken, and they take longer to heal.

Broken bones. — The two ends of a broken bone should be brought together in their correct position as soon as possible, before inflammation and swelling render this difficult. Of course, a surgeon should be called to set a broken bone. If the patient has to be carried some distance, care should be taken to prevent injury to the fleshy parts by the ends of the broken bone; the limb should be bound with handkerchiefs to a strip of board, or even to umbrellas or walking sticks, as temporary splints. Learn the first aid treatment for broken bones on page 419.

Dislocations and sprains. — A dislocation* sometimes breaks the ligaments surrounding it, producing inflammation.* This makes examination of it difficult, hence there should be no delay in procuring the necessary skill and restoring it to place.

A sprain* is an injury due to a sudden wrenching or tearing of the ligaments, as a result of which a ligament is lacerated or torn from its fastenings to the bone. A bad sprain may be more serious than a fracture,* and result in stiffness or in permanent weakness. Immediate rest is necessary. A cold footbath immediately after spraining the ankle is sometimes beneficial. If there is delay in treatment and the joint swells, then use hot water. Careful rubbing, very light at first and gradually increasing in vigor from day to day, may shorten the period of recovery. Learn the first aid treatment for a sprain on page 422.

Weak feet. — In discussing the foot it was pointed out that the feet are very important parts of the body. If we are to be able to do the many things in games and work that we will want to do we must have strong feet. Feet are not all beautiful and many people are ashamed of their feet. That is because they have deformed them by improper shoes and improper methods of walking. Notice the well-shaped use-

ful feet in Figure 60. What would happen to the feet in Figure 60 if placed in shoes of the type shown in Figure 62?

Foot exercises. — To strengthen the muscles of the feet the following exercises will be found useful:

1. Stand with the feet parallel about three inches apart. Roll outward on the outer borders of the feet.
2. Stand with the feet parallel about three inches apart. Raise on toes and then lower heels slowly with weight on outer borders of the feet.
3. Walk on outer borders of the feet with the feet parallel.
4. Sitting, — feet flat and parallel on the floor, raise the arch by attempting to draw the toes toward the heel.
5. Same as number four — standing.

Exercises to be done ten to twenty-five times daily.

Characteristics of a good shoe. — The choice of a shoe that will provide the necessary protection to the foot and that will not injure the foot is very important. Such a shoe will have a heel low and as broad as that of the wearer. The sole of the shoe should be, in outline, essentially the same as the outline of the foot and especially it should have a straight inner line. The shoe should fit tightly over the heel and should grip the foot through the instep, leaving plenty of room in the region of the toes. Compare the illustrations in Figures 67, 68, and 69 and keep these points in mind when buying your next pair of shoes.

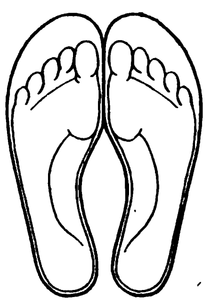


FIG. 67. — Shoes should be made to fit the foot.

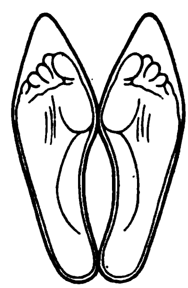


FIG. 68. — Feet should not be crowded to fit the shoe.

Deformities* of the spinal column. — This comes chiefly on account of the yielding nature of the cartilage. The

extent of the compressibility of cartilage may be realized if one's height is measured upon rising in the morning and again at night, when the loss in height sometimes amounts to nearly half an inch. The cartilages between the vertebræ

FIG. 69. — The two figures above represent young people who are victims of a custom that is foolish: the Chinese are giving up foot-binding. The lower figure represents young America, shod with healthful shoes, and ready for work or play.

are very thick, so as to give flexibility to the spinal column. This blessing also brings with it a danger of deformity. If the head is bent forward continuously in study or work instead of being held up, the upper cartilages are compressed in front, the ligaments stretch, and a deformity of the neck may result, causing the head to project forward. Working

with the desk low in front, or working upon the ground, may cause round shoulders.

Lateral curvature of the spine. — Tight clothing deforms the ribs, which are early altered because of the long cartilages. The binding down of the front ends of the ribs causes posterior curvature of the spine, with flat chest and round shoulders. Lateral, or sidewise, curvature (Fig. 70) of the spine is caused by constantly carrying the books, satchel, or other weight in the same hand; by writing at a desk that is too high; by hanging the head to one side; and by improper and insufficient food, so that the muscles are weakened. Figures 71 and 72 show the improper and proper ways to carry books. It is important that girls, especially, learn to carry books in the proper way at all times.

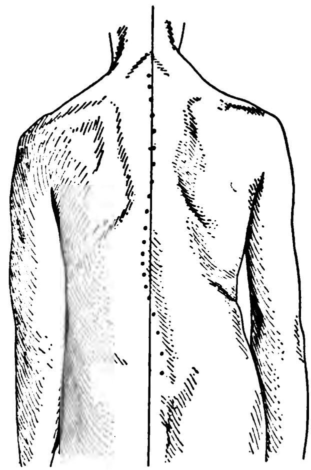


FIG. 70. — Such a condition prevents the boy or girl from playing freely in games. In most cases it can be prevented; in many, it can be corrected.

Posterior curvature of the spine. — Posterior curvature is caused by habitually bending over the work, and by slipping down in the seat or desk (Fig. 73), "trying to sit upon the small of the back." It is caused also by weakness of muscles, by wearing shoes with high heels, and by writing at a desk that is too low. In curvature of the spine, the cartilages become V-shaped and the ligaments stretched. Shoulder-braces should not be worn to correct round shoulders. If they hold the shoulders back they are doing the work of the muscles and so the muscles become weaker and less able to maintain a good posture. Corrective exercises * are necessary

in many cases, and they should be given by the teacher of physical education or the school physician. If an incorrect posture is habitually assumed in walking, in carrying books or otherwise, one should not expect to recover natural grace of form by wearing a brace. Exercise of the neglected

Fig. 71. — An improper way to carry books.

Fig. 72. — By distributing the books properly the posture may be held easily in correct position.

muscles, that is, opposite muscles, instead of those that were used excessively while acquiring the deformity, is a great aid. Posterior curvature has been improved by sleeping on the back on the floor or on a hard mattress.

Posture. — The bones are more or less flexible in childhood, so that the posture we assume while we are growing children will determine and control, very largely, the shape of our bodies when we become grown. If a young tree is

bent, it grows into a crooked tree. What is that saying, "As the twig is bent ——"? There are four positions which must be correct so that grace, strength, and control of the body will result when we are adults. These are the sitting, the lying, the standing,

FIG. 73. — Flat chest, round shoulders, and displacement of vital organs are produced by slipping forward on the seat.

FIG. 74. — This position is not only hygienic but also comfortable because the weight is balanced.

and the walking positions.

Sitting. — One should sit in a chair or at a desk so that the trunk is kept straight and any inclination should occur at the hip joint. This not only looks better but it allows the organs in the chest and abdomen to act in a free and unobstructed way. Select the good posture in Figures 74 and 75.

Lying down. — When the body is reclining, all the muscles should be relaxed. There should be no effort to hold the body in any particular posture. Does that mean that there is no instruction as regards lying? No! The proper lying position is on the right side or partially on the face.

Standing. — It must be remembered that the upright position of man is an acquired position. A long time ago the ancestors of man climbed and walked on "all fours." It is also true that the posture of man differs in different races. The standing posture of the Chinese is different from that of the Englishman. The posture of people of the same race varies because they are expressing different things in the way they stand. This is a very important fact. The body speaks all the time and tells many things by the position it takes in standing. We should be sure that we are having it tell the things that we are willing to stand for. Observe the walk of people on the street and see if you can tell what they are thinking about or how they are feeling. What do you express in your body as you walk to school. The standing position in order to be most efficient must be in balance. The weight must be carried on the balls of the feet. This does not mean that the heels are not to touch the ground. The head should be carried on top of the chest and not projected forward as if it grew from the

FIG. 75. — The sitting posture depends upon proper seats.

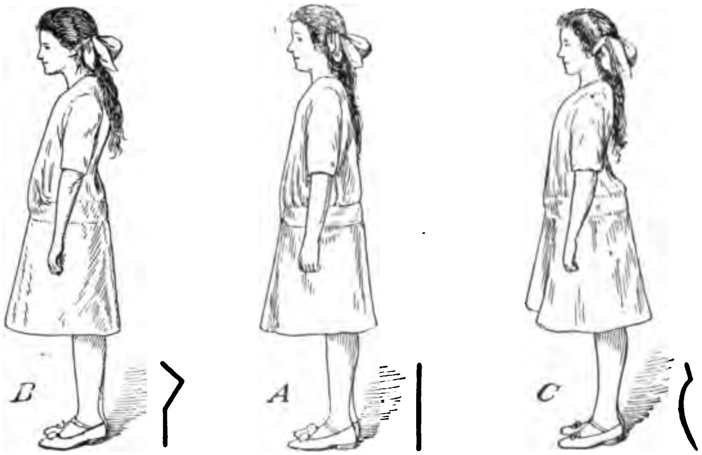


Fig. 76. — Good posture makes for health, happiness, and improves personal appearance. Write a legend for *A*, *B*, and *C* that tells what the girl is saying with her body.

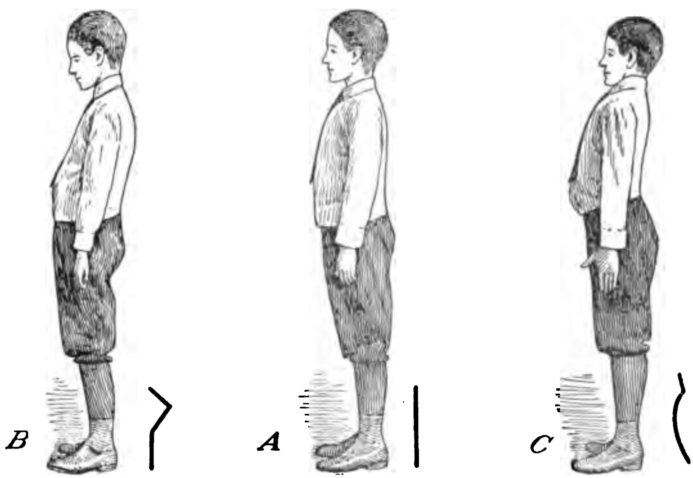


Fig. 77. — The boy with good posture is not only a stronger and more active boy, but his posture will be an asset in business or professional life. *A*, body erect, weight over the balls of the feet. *B*, body relaxed, no control and no balance, hence in a poor position for action. *C*, body stiff and bent backward — awkward.

front of the chest. Compare the postures in Figures 76 and 77.

Walking. — In walking, the weight should be carried on the outer side of the feet (Fig. 57), the feet should be placed on the ground parallel to each other (Fig. 60), the chest should be carried well forward (Figs. 76 A, 77 A), and the arms should swing easily at the side. In Figures 71–77 tell the good and bad points in the postures shown.

If the habits of the body in motion and at rest are incorrect, if the parts are not clothed properly, the flexible bones in childhood will be malformed. There are many who suffer in adult life because they have worn improper shoes and clothes, and have walked and sat in incorrect postures. Bow legs are often caused by encouraging children to walk while too young. They may also result from improper methods of feeding, while infants.

Fig. 78. — Appearance of the face of a boy who did not have his adenoids removed. (By courtesy of Dr. Frank S. Mathews.)

Essential facts in the growth and development of bones. — For proper growth and development, the bones must be used correctly. Any constant incorrect use will show in distorted and crooked bones, producing a form that is less able to move quickly and easily, and hence a form that is less efficient. Good food and pure air brought by a vigorous circulation are essential. Poor or indigestible food, stimulants,* and poisons affect the health and strength of the bones. Surgeons report cases of fracture occurring in persons having the alcohol habit,

where the bones would not unite by bony material, but remained flexible and useless. Indulgence in alcoholic liquors, especially wine, is a very common cause of gout, a disease of the joints. Smoking in boyhood often prevents the proper development of the long bones and a stunted stature results. It must also be remembered that growing parts are deformed by conditions that interfere with proper functioning. In this way, adenoids may cause marked deformity of the bones of the face (Fig. 78).

APPLIED PHYSIOLOGY

Exercise I

1. What are the common faults found in shoes and how do such shoes injure the feet? Most people assume the following rule in selecting a shoe: If you can just draw on a shoe without much effort and sit with it on the foot for ten minutes, it will be comfortable to walk in and wear all day. Yet such a shoe is one size too small for walking. Many makers no longer number their shoes plainly because of the vanity of some purchasers. A new shoe should be as comfortable as an old one. Persons who, because of silly jokes about big feet or for other reasons, have the idea that the shoe should leave no extra room, but should fit as if it were covering a wooden foot, will always get uncomfortable shoes.

2. If a shoe is too loose, it slips up and down at the heel and chafes the skin there. If too tight, there is pressure on the toes, which causes a corn or ingrowing nail. Have your shoes been correct or have they been too loose or too tight?

3. How many sprained ankles have you known of? Were the sufferers mostly boys or girls? Why?

4. What is the general arrangement of the bones of the foot? Does the weight of the body come upon the middle of the arch? How can this arch be injured and what is such a deformity called?

5. Why is it that people who grow up in warm climates are more likely to have high arched insteps and elastic feet than those who pass their childhood in cold climates?

Exercise II

6. What in the composition of a bone gives it stiffness? hardness? toughness? flexibility?

7. Should chairs and benches have straight backs?

8. Why is a chair back that is very slanting often injurious? Why is a very deep chair injurious if deep enough for the front edge to strike the occupant behind the knee?

9. Why does a young child usually crawl before it walks?

10. Which girdle is attached directly to the spinal column? Which girdle is attached indirectly?

11. Why is the arm so often dislocated at the shoulder?

12. High pillows may cause what deformity?

13. Should a young child be urged to stand or walk?

14. What part of a long bone is composed of compact tissue? Of very porous tissue?

Exercise III

15. Could the neck be broken and death result without breaking a bone?

16. What would be the result if the ligaments were composed of the yellow fibers of connective tissue instead of the white fibers?

17. If a child's feet be allowed to dangle from a high seat, what will be the effect?

18. When the palm is turned upward is the radius parallel or crossed with the ulna? When the back of the hand is up?

19. Why should one always sit and walk erect?

20. In a long bone what is chiefly a storage tissue, saving food for future use?

21. Ligaments are of very slow growth. This accounts for the tedious nature of the recovery from what kind of accidents?

22. Observe how many of your classmates sit " slid forward " in the seat, and report in recitation the result of your count.

23. When the school is marching out, count those who walk with the head protruded.

24. A " bone felon " is often caused by an infection beneath the periosteum. Why should it be lanced?

25. What is the first aid treatment for a fracture? A sprain?

Exercise IV

26. Is it correct to walk with the weight on the outer side of the foot? Why?

27. Determine, by placing the wet feet on a piece of paper, where the weight comes. Let the weight sag inward and observe how this position increases the size of the imprint.

28. Make a tracing on paper of the feet in an abducted position and in a parallel position.

29. Measure your height in the morning and evening of the same day. Is there a difference?

30. Notice the difference in breathing while in the correct and incorrect sitting position.

LABORATORY EXERCISES

Experiment 1. To study the organic and inorganic * parts of bone.

Material. — Hog's rib, glass beaker, dilute muriatic acid, and alcohol.

Method and observation. — Place the rib free from all muscle and connective tissue in the beaker and cover with the acid. Leave in the acid until the bone becomes elastic. When the mineral (inorganic) matter has been dissolved, the bone can be easily bent. Remove the excess of acid and preserve the rib in alcohol.

Experiment 2. To study the foot in relation to the shoe.

Material. — White paper, ruler, and pencil.

Method and observation. — Place the bare foot on the paper and draw an outline of the foot. Measure with the ruler the width of the foot in the instep region and the length of the foot from toe to heel. Measure the width of the shoe in the same region as that taken for the foot; measure the length of the shoe. Compare the two sets of measurements.

Experiment 3. To determine the proper height of the school seat.

Material. — Ruler or yardstick.

Method and observation. — With the foot flat on the floor measure the length of the leg from the floor to the under surface of the knee. How many inches is it? Measure the height of the seat from the top of the forward edge to the floor. How many inches is it? The leg measurement should be one inch more than the seat measurement. Are your school seats adjustable. Are they properly adjusted?

GLOSSARY

Corrective exercises. — Exercises usually of a passive type at first and later of an active type for the purpose of correcting deformities of the skeleton.

Deformity. — A change from the normal.

Dislocated — Displaced. The term here refers to the displacement of a bone from its normal position in a joint. When there is a dislocation, there results a deformity.

Fracture. — A break. Used with reference to bones. A broken bone is called a fracture. In a fracture, the deformity may not be seen except by an X-ray.

Inflammation. — A process in the body characterized in most cases by heat, redness, swelling, and pain in the part affected.

Inorganic. — Not being or having been a living organism. Refers to substances in chemistry that relate to the world of metals and their compounds.

Paralysis. — Loss of the power of contractility in the voluntary or involuntary muscles of the body.

Sprain. — The injury to ligaments of a joint. This may be a stretching, or, if severe, a real tearing. The word strain is applied to the same sort of injury occurring in muscle.

Stimulant. — A substance that excites action in the body whether acting on the nerves through the skin or after getting into the circulation. Typical stimulants acting on different parts and in various ways are spices, mustard, camphor, ammonia, strychnin, light, heat, electricity, joy, hope.

Surgeon. — One who by training, skill, and experience is able to treat injuries and conditions of abnormality by means of manual methods or by the use of instruments.

CHAPTER VII

THE MUSCLES AS THE MOTOR MACHINERY OF THE BODY

I. What the Muscles Do.
II. Muscles and Nerves.
III. Kinds of Muscles.
  Voluntary
  Involuntary
  Cardiac muscular tissues
IV. Voluntary and Involuntary Muscles Compared.
V. The Attachment of Muscles.
VI. How Muscles and Bones Coöperate.
VII. Names and Positions of Muscles.

What the muscles do. — We have learned that motion is one of the properties of protoplasm. What are the other properties? A very interesting fact of physiology is that the cells of the body, such as muscle, nerve, skin, and bone cells and the cells of the different organs, have become specialized through the development of a certain property at the expense of other properties. For example, the muscle cell has developed to a high point of efficiency the property of contraction; the nerve cell has specialized in conductivity and irritability. This specialization of function was referred to under the head of division of labor. How does this same principle work in the society of men? Movement of the body, which is made possible by this specialization of muscle, is one of the essentials of life. The individual who cannot move is handicapped greatly, and the ability to move

easily, gracefully, and with the body in control is greatly to be desired.

Muscles and nerves. — Now, the one essential condition for contraction of the muscles is stimulation by the nerves. If an impulse is not sent to the muscle, the muscle cannot contract. Therefore, it must be remembered that the muscle and its nerve are to be thought of as a unit. For this reason the strength of a muscle is not dependent entirely upon its size. People who think that large muscles are a sign of health, and that large muscles give strength and vigor, are very much mistaken, if they depend only upon muscular strength. The development of the will is very important. The body has been compared to a steam engine. To what parts of the engine may the muscles be compared ?

We are hearing a great deal to-day about eugenics.* This word means "favorable birth." The eugenic movement aims to improve the physical, mental, and moral qualities of the race. It seeks to improve the quality of life in the nation. Now muscle and nerve tissues will have a good heredity,* they will be strong and efficient in proportion to the vigor and strength of the protoplasm from which they come. The science of eugenics aims at ends which should encourage all thoughtful young persons so to live that they will keep strong and healthy.

Kinds of muscles. — Muscular tissue occurs in nearly every organ. It helps to form the walls of the blood vessels, and assists in the circulation of the blood; the eyeballs are moved by six sets of muscles; the act of swallowing is performed by muscular contraction in the esophagus; the contraction of the muscles in the walls of the stomach produces the motion by which the food is mixed; in the intestines the muscles keep the partly digested food in motion; the muscles in the limbs enable us to move and work; the heart is chiefly muscle; the muscles in the chest and trunk enable us to breathe; those in the larynx are used in talking.

Muscles have been divided into two classes, voluntary and involuntary. The first class is under the control of the will, either at all times or part of the time; the second is never under the control of the will; their work goes on quite independently of the will and even during sleep. Can you assign to their proper classes the muscles named in the preceding paragraph?

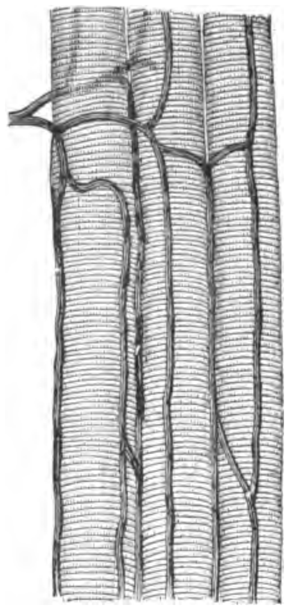


FIG. 79. — A portion of three striated muscle fibers, moderately magnified. Showing the capillary vessels (dark).

Voluntary (*striated*) *muscles.* — It is to be remembered that a muscle is made up of cells which are specialized to perform the function of contracting. For the carrying out of this purpose, they have developed fibers within their protoplasm. The contraction of a muscle is caused by the contraction of the individual fibers which compose it. Each fiber shortens in length and becomes proportionally thicker; the sum total of the contractions of these fibers taking place at the same time makes up the contraction of the whole muscle. The number of fibers lying side by side determines the thickness of the muscle, and the amount of strength with which it can contract; while the number of fibers lying end to end determines the amount of shortening or contraction of which the muscle is capable. When the muscle is habitually used, it becomes larger, finer, darker, and stronger.

Voluntary and involuntary muscles are not constructed exactly alike. Examined under the microscope, each fiber of a voluntary muscle shows bright bands alternating with

dark bands, running across it (Fig. 79). These bands give the whole muscle a striated or striped appearance under the microscope, and this kind is, therefore, called striated muscle. The fibers are bound together by connective tissue into bundles called fascicles and these again into larger bundles. The connective tissue surrounding the bundles can be plainly seen in chipped beef, also in raw or boiled beef. The voluntary muscles are darker red than the involuntary. Lean meat is made up of these muscles. They are near the surface, but their outlines under the skin are obscured to a greater or less degree in different persons, according to the thickness of the layer of fat between the muscles and the skin. These muscles are usually attached to bones. They contract quickly, while the involuntary muscles contract slowly.

Involuntary muscles (*non-striated*, *smooth*). — Involuntary muscles are found in the walls of the alimentary canal, the bladder, the esophagus, and several other organs; all such muscles are composed of fibers which are not striated, and are, therefore, called plain muscle fibers. A striated fiber is about one inch in length and $\frac{1}{500}$ of an inch in thickness and is shaped somewhat like a cylinder; it possesses several nuclei. A non-striated muscle fiber is not more than $\frac{1}{400}$ of an inch in length, has the form of a very slender spindle, and contains one nucleus (Fig. 80). The fibers interlace and are held together by fine connective tissue.

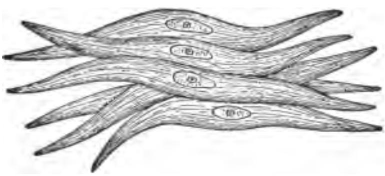


FIG. 80. — Fibers of non-striated muscles, or involuntary muscles.

Cardiac muscular tissue. — Cardiac* muscular tissue, of which the heart consists, differs from both striated and plain muscular tissue (Fig. 81). Its fibers possess one nucleus,

like plain fibers; they are not spindle-shaped and narrow, however, but broader and cylindrical. They are, moreover, faintly cross-striated by light and dark bands. We may say, therefore, that although the heart is in every respect an involuntary muscle, it has more resemblance to striated than to plain muscles. The many muscles used in breathing are at times voluntary, and at other times involuntary; but they are all striated muscles with the usual structure.

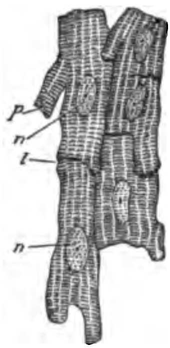


FIG. 81. — Two cardiac muscle fibers. *n*, nucleus; *l*, line of junction between the two cells; *p*, process joining a similar process of another cell (magnified 400 diameters).

Voluntary and involuntary muscles compared. — Compare the voluntary and involuntary muscles by writing in two columns headed, Voluntary Muscles and Involuntary Muscles, the facts concerning their Control, Structure, Color, Position in Body, Attachment, Rate of Contraction, Number of Nuclei, Length of Fibers, Breadth of Fibers, Shape of Fibers. (Place these titles in a third column.)

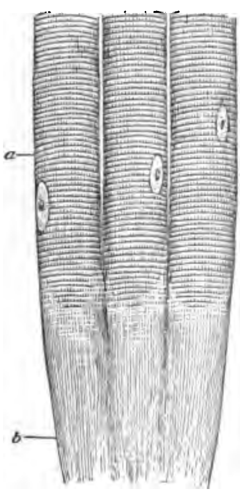


FIG. 82. — Striated muscular fibers (*a*) terminating in tendon (*b*). Many other fibers would attach to this tendon.

The attachment of muscles. — The involuntary muscles are usually found in the wall of organs that have cavities. They are sometimes called the visceral muscles because the internal organs are called the viscera. The quicker, stronger-acting voluntary muscles are called the skeletal muscles because nearly all of them are attached to bones. There are about five hundred

voluntary muscles. By studying the figures you will notice that the middle portion of these muscles is usually large and full, and that the muscles taper to small cords at the ends (Fig. 82). The muscles of the calf move the foot, and the muscles of the forearm move the hand. If the full round muscles extended down over the wrists and ankles, it would make these as large around as the forearm or calf, and the wrists and ankles would be very clumsy and awkward. It is found that the connective tissue which binds the fibers of a muscle into bundles and forms sheaths for the bundles, extends beyond the muscular tissue and unites to form a dense, inelastic, glistening white cord called a tendon. The fibers are very closely packed together and make a very strong cord. One no thicker than a lead pencil is strong enough to support twice the weight of the body. A tendon contains no nerves and very few blood vessels. Some muscles have a tendon at only one end; some have no tendon but are attached directly to bones. Find muscles without tendons by studying the figures. The cordlike nature of tendons can be ascertained by feeling the tendons under the knees, called hamstrings, or the tendons in the angle of the elbow.

FIG. 83. — Diagram to show the action of the biceps muscle of the arm. The two tendons by which the muscle is attached to the scapula are seen at *s*; *r*, the point of attachment of the muscle to the radius; *e*, the elbow joint; *h*, the weight of the hand.

How muscles and bones coöperate. — When you grasp a heavy weight in the hand and lift it by bending the elbow, where is the muscle that does the work? You will easily find it in the upper arm. This muscle is called the

biceps because it is attached to the shoulder blade above by two tendons. The lower arm acts as a lever * with the fulcrum,* or fixed point of the lever, at the elbow (Fig. 83). It is easy to see that a slight contraction of the biceps muscle will move the weight a greater distance than is accounted for by the shortening caused by the actual contraction of the muscle. This is what the bones usually accomplish for the muscles; they change a slow, short, inadequate movement into a long, swift movement. While the muscle contracts an inch, the bone may move a foot. The bones thus add greatly to the range and rate of motion.

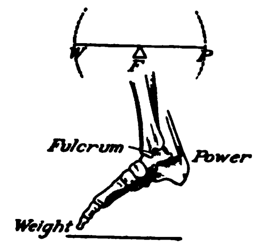


FIG. 84.—Tapping floor with toe. Lever of first order.

Figures 84, 85 and 86 show the three orders of levers. In the lever of the first order, the fulcrum (*F*) is between the power (*P*) and the weight (*W*). In the lever of the second order the weight is between the other two, and in the lever of the

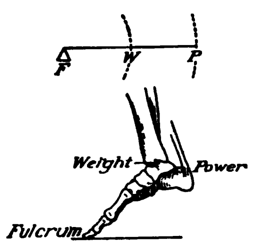


FIG. 85.—Raising weight of body upon ankle. Lever of second order.

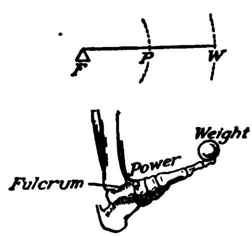


FIG. 86. — Raising a weight upon toes. Lever of third order.

third order the power is between the others. In Figure 83 the biceps muscle acts on the radius and ulna fastened together as one, turning at the elbow as a fulcrum; the weight to be lifted is in the hand. This is evidently a lever of the

third order with the power between the other points. In this case it takes a force in the muscle equal to about six pounds to raise one pound in the hand.

Figure 87 shows how the muscles may act upon the bones as levers to prevent the bones from turning upon the joints

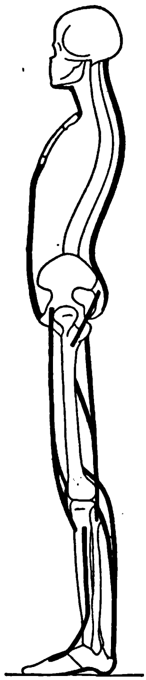


FIG. 87.—Diagram of the muscles that keep the body erect.

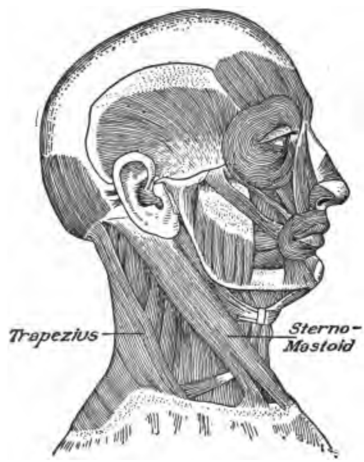


FIG. 88.—Muscles of head and neck. Find the following muscles: Chewing muscles; scalp muscles; bowing muscle of one side; muscle that holds head erect (upper part of trapezius at back of neck); muscle that squints the eye; muscle that pouts the lips; muscle that broadens the mouth in smiling; muscle that raises corners of mouth; muscle that draws down corner of mouth.

as fulcrums; thus the body is held erect. Where are the muscles located that keep the body from falling or bending forward? From falling backward? Which of the two sets is in front? What kind of lever is illustrated by the head tilted upon the first vertebra?

Names and positions of muscles. — A few of the important muscles are here mentioned: The scalp muscle (Fig. 88) passes over the top of the head; it raises the skin over the eyes, and (in some persons) moves the scalp. The two pairs of chewing muscles are the temporal * and masseter * (Fig. 88). You can feel the temporal muscle swell and harden if you

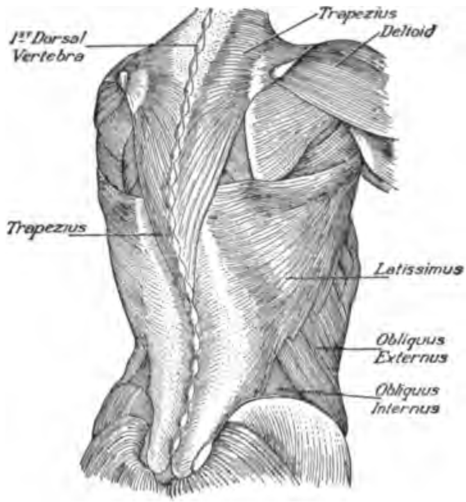


Fig. 89. — Principal muscles of the back. Trapezius draws shoulder and head back; deltoid raises whole arm; latissimus, climbing muscle; obliquus internus and obliquus externus draw abdominal wall in and force abdominal contents against the diaphragm, thus expelling air from lungs.

place your finger on the temple and close your mouth forcibly. In the same manner you may feel the contraction of the masseter by placing the fingers just below the cheek bone. The muscle used in bowing passes obliquely down on the side of the neck to the collar bone (Fig. 88). It can be felt as a thick band; when the head is turned to one side, it stands out as a ridge. When one of the two acts alone, it turns the face so as to look to the other side. When both act, they bow the head. The deltoid * (Fig. 89), or shoulder

cap muscle, raises the whole arm outward and upward from the side. Can you locate it by the feeling of fatigue after raising the arm twenty times? The biceps can be seen and felt contracting on the front of the arm when bent at the elbow. The triceps* is on the opposite side of the arm and

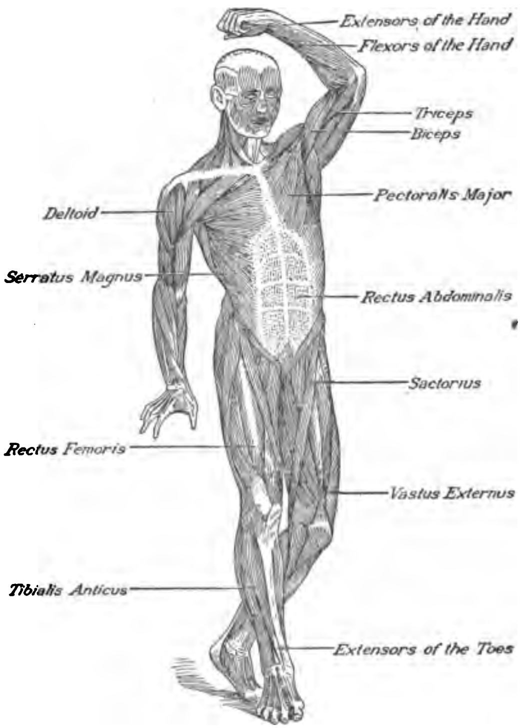


FIG. 90. — Full-figure muscles (front).

straightens the elbow (Fig. 92). Which is used in striking a blow, the biceps or the triceps?

The sartorius* (*tailor*) muscle (Fig. 90) is nearly two feet long and is the longest muscle in the body; it passes from the outer side of the hip bone to the inner side of the leg below

the knee, and is used in crossing the leg; because of the position assumed by a tailor at work it is named the tailor's muscle. The gastrocnemius* is a thick muscle in the calf of the leg, which raises the heel (Fig. 91). When is it used? It is attached to the heel by the largest tendon in the body,

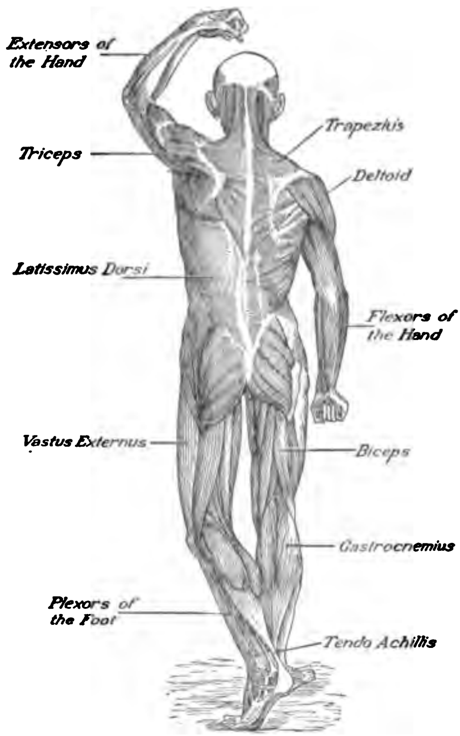


Fig. 91. — Full-figure muscles (rear).

called the "tendon of Achilles." Ask the teacher why it is so called, or read the story of Achilles.

The trapezius* (*four-sided*) (Figs. 89 and 91) is a large muscle covering the back between the shoulders. It draws the shoulders back and holds up the head. Can you find

the climbing muscle (Fig. 89), or the muscle that draws the arm backward and downward (latissimus or *broadest*)? When a person hangs by the hands, it helps to raise the body. It is a large spread-out muscle extending from the humerus to the vertebral column.

There is a great fan-shaped muscle called the pectoralis (Fig. 92), which attaches the arm to the front wall of the

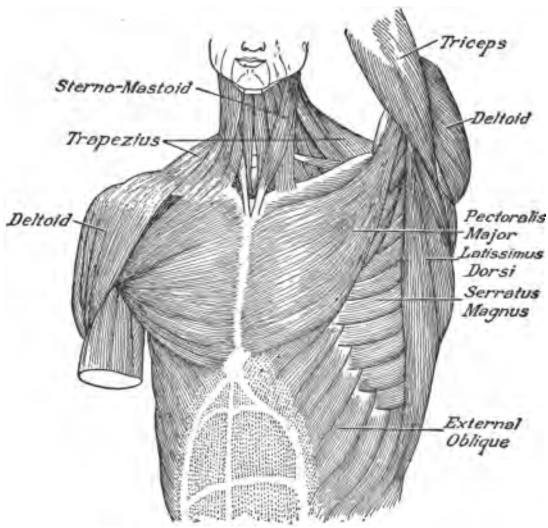


FIG. 92. — Superficial view of muscles of upper part of trunk, from the front (Allen Thomson).

thorax. Muscles are arranged in opposing sets. Flexors oppose extensors, abductors act against adductors. Two muscles with opposite action or function are said to be antagonists.* When antagonistic muscles work together in harmony, then the movement is graceful. Awkwardness results from too strong contraction of one of the antagonistic groups. In learning a new movement, more muscles than are necessary are used at first. The beginner in skating, for

example, should not try too hard, should not be too tense, and the coordination will come quicker.

Muscles are named from their shape, as deltoid (like the Greek letter delta, Δ); their location, as tibialis (near the tibia); their action, as flexors; their manner of attachment, as triceps (three-headed).

GLOSSARY

Antagonist. — In muscles, a muscle that acts counter to another muscle.

Cardiac muscle. — The muscle of the heart. The word comes from the Greek word *kardia* meaning heart.

Deltoid. — The muscle that covers the point of the shoulder. So called because of its shape. It is triangular like the Greek letter delta.

Eugenics. — The science of improving the human race. Term first used by Sir Francis Galton.

Fulcrum. — The support on which a lever rests and by means of which it obtains its power.

Gastrocnemius. — A large muscle of the leg so called because of its large belly (from Greek *gaster*) and its situation on the lower leg (from Greek *knemis*, meaning greave, or *kneme*, meaning lower leg).

Heredity. — The tendency shown by an organism to develop in the likeness of its forbear.

Lever. — Usually a straight bar turning on a fixed point as the fulcrum and serving to produce a pressure from the power moving the lever to the weight or resistance to be moved.

Masseter. — A muscle of the jaw used in chewing. So called because of its function, from the Greek word, *maseter*, a chew.

Sartorius. — A long muscle of the thigh; so called from its use in crossing the legs, as of tailors. *Sartor* meaning a patcher, hence a tailor.

Temporal. — A muscle that is located at the side of the head near the temple.

Triceps. — A muscle at the back of the upper arm. It has three heads.

Trapezius. — A large flat muscle of the back shaped like a trapezoid when the two muscles are viewed together.

CHAPTER VIII

THE MUSCLES IN ACTION AND THE HYGIENE OF EXERCISE

I. The Neuro-muscular Mechanism.
  Response of the muscle to the nerve stimulus
  Coördination of muscles
II. Muscular Energy.
  Production
  Expenditure
III. Muscular Tone.
IV. Muscular Activity and Fatigue.
V. The Effect of Stimulants and Narcotics on Muscular Action.
VI. The Effect of Exercise on Growth.
VII. The Relation of Exercise to Health.
VIII. Forms of Exercise.
IX. Over-development of the Muscles.

The neuro-muscular mechanism. — If the nerve to the muscle is severed, the muscle cannot be contracted no matter how hard we try. Is a muscle and its nerve a unit? This unity is sometimes called the neuro-muscular mechanism. If this mechanism is called psycho-motor,* to what does it refer? Does neuro-muscular refer to structure?

Response of the muscle to the nerve stimulus. — When a muscle cell receives a stimulus from its nerve, it changes its shape by growing shorter; it does not increase in size. When a boy shows his muscle by flexing his elbow, the biceps muscle shortens and becomes thicker in one part, but the entire muscle does not take up more room than it did when in a relaxed condition.

Coördination of muscles.* — Would you like to see two persons try to thread a needle, one holding the thread and the other the needle? Would they succeed well? Or in so simple a matter as the use of the knife and fork in eating, could it be easily done if one holds the piece of meat with the fork while the other tries to cut it? Why is it that the right hands of two persons cannot work so well together as the right and left hands of one person? It is because of the nervous connection between the hands of the same person, so that one hand knows just what the other is doing.

Let us think of what takes place in our bodies when we throw a stone at a mark. At the same time we see the mark, hold the stone in the hand, and throw it. In throwing a stone, at least a dozen muscles are used. Each one of these must contract at the right time and in the right way, or the stone will miss the mark. Each muscle shortens under the influence of a nerve impulse brought from the brain by a motor nerve. If one muscle shortens an instant too soon, or a little too much, the stone goes to one side. This working together of the muscles by the aid of the nerves is called coördination. Coördination is necessary, even in standing erect.

Muscular energy. — It is well known that the activities upon which life depends involve a continuous expenditure of energy. The beating of the heart, the secretion by glands, the contraction of muscles, the discharge of nerve impulses — all expend energy. It is also well known that such activities involve a constant breaking down of chemical compounds. These compounds come from the food eaten and they may be used at once or after being stored in the body. These two facts then are closely associated:

1. The constant breaking down of chemical compounds.
2. The continuous expenditure of energy.

Production. — But just how is energy formed in the body? It is formed by the chemical action of the compounds which

come from the food we eat. All the energy that is available in the muscle for contraction has its origin in the chemical changes that follow after the nerve impulse has come to the muscle. We shall understand better what energy is when we remember that heat and energy are the same. The physicist says that heat is the lowest form of energy. The chemist can show that chemical combinations liberate heat, which tends to express itself as energy. Consider the laboratory experiment on page 56. So in the body, the chemical union of food elements produces energy which appears in the different cells in the form which is of use to that cell. The voltaic cell is similar to the nerve cell and the electric current produced is similar to the nerve impulse of the nerve cell. The heat produced in the test tube by the action of the zinc and sulphuric acid represents the heat produced in the muscle after the chemical action of the food compounds. What starts the chemical action of the food elements in the muscle?

The conversion of food into heat and energy is going on in the body all the time so long as life exists. It is less in sleep and more during activity. It is maintained by the food eaten daily. Is this an argument for nutritious foods, properly cooked and carefully eaten? If no food is eaten, it goes on just the same and uses up the cells of the body. How can weight be reduced? More energy is required for stout than for thin persons; more in cold weather than in hot, more in fever than in health. A growing child requires more energy in relation to its weight than an adult. If a child weighs 60 pounds and a man weighs 150 pounds, which will require more energy? If the child needs 1920 units of heat and if the man needs 2850 units of heat, which requires more in relation to its weight? The heat energy necessary for muscular contraction may be obtained from any of the three foodstuffs — carbohydrates,* fats,* or proteins.* It is believed that the carbohydrates afford the most favor-

able source of supply and they will be used first, if present in sufficient amount. The blood in the arteries going to the muscles contains more sugar than the blood in the veins coming from the muscles. Would sweet chocolate be a good food to carry on a long tramp?

Expenditure. — It is found that the use of many small muscles is much more exhausting than the use of a few larger ones. This is on account of the nerve energy consumed. A drummer beating a big bass drum may do more muscular work than one who plays a tune softly on the piano, but the piano playing exhausts the performer much sooner. This is because the movements of the wrist and fingers employ thirty muscles and a great number of nerves. The striking of the keys with the ends of the fingers, where some of the most sensitive nerves of the body terminate, may have some effect also, and may help to explain why so many persons, especially girls, who take little other exercise, have become nervous wrecks from piano playing. Continued typewriting and penmanship are exhausting, but typewriting gives variety of motion, while handwriting calls for a monotonous use of the same muscles.

The fact that the muscles are arranged in pairs as antagonists of each other may have a calamitous effect in the case of persons with ill-regulated nervous system. Such persons on account of anxiety or worry, doubt, or over-active desire, keep their muscles drawn tense, the antagonists pulling against each other, and after a while they lose the power of relaxing their muscles. They wear anxious expressions, because the muscles of the face are never relaxed or in repose. Their movements are nervous and jerky instead of graceful and easy. Their breathing is not deep and natural, and their voices, therefore, are not even and steady. They cannot be perfectly still, but chew gum or a pencil, rock the chair, bite their finger nails, or claw their knuckles. Have you any friends who are handicapped by this condition of

over-tension? When such people listen to a sermon, their backs get tired because they cannot relax comfortably in the seat. When they lie down, they try to hold the body on the bed, and instead of relaxing the muscles of the neck, try to hold the head on the shoulders.

Over-tension is common to adults in cold climates, but it is also known in warm climates. A graceful person, like a child, uses just the muscles necessary for any act, and no more. Ease of manner, as well as health, makes important the correction of conditions to which all hurrying, ambitious persons are liable in an age of keen competition and of ambition for learning and distinction.

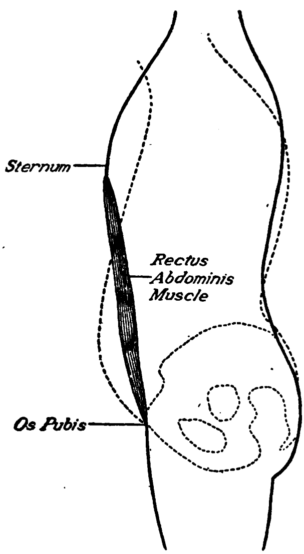


FIG. 93. — Diagram of good posture showing well-developed rectus abdominis muscle in tonic contraction; dotted line showing poor posture with relaxed and flabby abdominal wall.

Muscular tone. — That the muscles may be always ready for use, they must not be entirely soft and flabby, but should be under a condition of very slight contraction, called tone (Fig. 93). We find that the muscular walls of the blood vessels possess tone. It is this condition of slight contraction which causes a wound in the flesh to gape open. If a tendon is cut, the muscle shortens on account of its tone. If the nerve going to the muscle is cut, the muscle lengthens a little, that is, it relaxes, showing that there must be faint but constant impulses coming through the nerve to keep the muscle in tone. When one is asleep, the body does not lie perfectly straight, but the joints are slightly bent to allow relaxation.

Muscular activity and fatigue. — If we suspend a frog's muscle from a muscle clamp, and attach the tendon to a writing lever, on stimulation of the muscle by an electric current we can record the contraction that results. In a series of contractions (Fig. 27) of a fresh muscle, there will be seen a gradual increase in height of the contractions (called, Die Treppe — *the staircase*) until the maximum is reached (Fig. 27); and presently the height will decrease. The height will gradually fall until no contraction at all occurs, no matter how strong the stimulus. The increase in power at first is due to the increased irritability of the muscle cells brought on by the presence of chemical substances formed in the muscle during the production of energy. These are known as fatigue substances. They are forms of chemical compounds which represent the waste material left after the combustion in the muscle, and in this respect resemble the ashes left in the furnace. After these fatigue substances increase in amount, the irritability of the muscle is lessened, so that there is a decrease in the height of the contractions (Fig. 27). What purpose do warming-up exercises have in relation to performing an athletic feat?

When fat or carbohydrate is used as the source of energy for muscular contractions, the waste products are carbon dioxide, mono-potassium phosphate, and lactic acid. When proteins* are used as energy, the waste products from these are in the forms of urea, uric acid, creatin, and others. Now, all these substances interfere with the working of the muscle. By getting into the blood stream and by being carried to other parts of the body, the effects from a local activity may be felt all over the body. Fatigue of one part lowers the efficiency of the rest of the body. These fatigue products are removed chiefly by the kidneys and lungs. Rest, sleep, and food to restore the chemical forces used are necessary for complete recuperation of the body after a fatiguing task.

Sleeping is the best way of resting. What are the other lines in this quotation?

"Sleep that knits up the ravell'd sleave of care."

Who wrote these lines? Did he know much about physiology? Is such knowledge of value to a poet and a writer? Name the professions in which knowledge of physiology is absolutely necessary. Is it of value to a father? To a mother?

In Figure 94 two graphic* representations of muscular contractions are shown. In *A* the contractions at the be-

FIG. 94. — The effect of rest on muscular contractions. *A* shows the contractions of a fresh muscle. *B* shows the contractions of the same muscle with a rest of five minutes after doing the work shown in *A*.

ginning are higher than those in *B*. Between *A* and *B* there was a rest of 5 minutes. It is to be noticed that the contractions in *B* at the beginning are higher than those at the ending of *A*, but not as high as those at the beginning of *A*; in addition it is seen that fatigue comes quicker in *B* than in *A*. These contractions are of the muscle that abducts the index finger.

The effects of stimulants and narcotics* on muscular action. — The weaker forms of alcohol, such as ale and beer, cause a change into fat of much of the albumin* in muscle cells, thus bringing about a bloated and flabby condition, called fatty degeneration.* It may even reach the heart,

causing a dangerous disease called fatty degeneration of the heart. There are other causes of this condition. If an athlete who has developed enormous muscles suddenly ceases to train, his muscles may undergo fatty degeneration. Through the narcotic or deadening effect of alcohol, the nerves become less sensitive, and fatigue is not so readily perceived. This unawareness of the real bodily condition gives the drinker a deceptive feeling of strength and power.

It has been found that two hours after taking two ounces of whisky mixed with eight ounces of water, the muscular strength of the man experimented on was reduced one third. This means that a lifting power of three hundred pounds was reduced to two hundred pounds. An old drunkard usually has a dragging gait and trembling hands. Coffee, which is a stimulant, sometimes causes a twitching of the eyelids; this is a sign that the body is being irritated.

The effect of exercise on growth. — Exercise has a stimulating effect upon growth. This effect has been recorded many times by scientific observers. Henry G. Beyer, M.D., reported observations on the growth of 188 naval cadets who took special systematic exercise, and compared it with the usual growth of cadets of the same age.

There was an increase in height of more than one inch above that which took place without the special exercise.

The increase in strength was five times as much as the normal increase.

There was an increase in weight of 77 pounds in the four years during which the observations were made.

There was an increase in lung capacity * of 1.72 liters.

The growth of the body in height and weight is determined partly by the influence of heredity and partly by the kind of care the body receives. Height is determined largely by heredity, and weight largely by environment. The following table by Dr. Holt shows the weight, height, and circumference of the head and chest from birth to the sixteenth year:

Age		Weight in Pounds	Height in Inches	Chest in Inches	Head in Inches
Birth	Boys	7.55	20.6	13.4	13.9
Birth	Girls	7.16	20.5	13.0	13.5
6 months	Boys	16.0	25.4	16.5	17.0
6 months	Girls	15.5	25.0	16.1	16.6
12 months	Boys	20.5	29.0	18.0	18.0
12 months	Girls	19.8	28.7	17.4	17.6
18 months	Boys	22.8	30.0	18.5	18.5
18 months	Girls	22.0	29.7	18.0	18.0
2 years	Boys	26.5	32.5	19.8	18.9
2 years	Girls	25.5	32.5	18.5	18.6
3 years	Boys	31.2	35.0	20.1	19.3
3 years	Girls	30.0	35.0	19.0	19.0
4 years	Boys	35.0	38.0	20.7	19.7
4 years	Girls	34.0	38.0	20.5	19.5
5 years	Boys	41.2	41.7	21.5	20.5
5 years	Girls	39.8	41.4	21.0	20.2
6 years	Boys	45.1	44.1	23.2	
6 years	Girls	43.8	43.6	22.8	
7 years	Boys	49.5	46.2	23.7	
7 years	Girls	48.0	45.9	23.3	
8 years	Boys	54.5	48.2	24.4	
8 years	Girls	52.9	48.0	23.8	
9 years	Boys	60.3	50.1	25.1	
9 years	Girls	57.5	49.6	24.5	
10 years	Boys	66.6	52.2	25.8	21.0
10 years	Girls	64.1	51.8	24.7	20.7
11 years	Boys	72.4	54.0	26.4	
11 years	Girls	70.5	53.8	25.8	
12 years	Boys	79.8	55.8	27.0	
12 years	Girls	81.5	55.1	26.8	
13 years	Boys	88.3	58.2	27.7	
13 years	Girls	91.2	57.7	28.0	
14 years	Boys	99.3	61.0	28.8	
14 years	Girls	100.3	60.3	29.2	
15 years	Boys	110.8	63.0	30.0	21.8
15 years	Girls	106.4	61.4	30.0	21.5
16 years	Boys	123.7	65.6	31.2	
16 years	Girls	118.0	61.7	30.8	

The relation of exercise to health. — It was learned on page 6 that the muscular system developed to make loco-

motion possible. Animals of every species are dependent upon movement for obtaining the necessities of life. The important thing for us to remember is that for innumerable years muscles have been a part of the human body as constructed to-day. We have inherited, therefore, a muscular system, and with that system we have inherited the need for activity. Young people are usually very active, but too often, after school days, they lead physically inactive lives in office, store, or home. Some people think they can maintain health and strength by a two-minute drill in their room before retiring. Health cannot be obtained or maintained by such condensed pill-like measures. There must be outdoor life and outdoor exercise if the human body is to keep its inheritance. The boy and girl in school and college should learn to enjoy and to become proficient in some game or sport, so that in adult life this activity may be followed. Too often in adult life men and women are so weak physically that they do not enjoy exercise. Such condition of the body is unfavorable to the maintenance of health, to say nothing of the resulting effect of bad disposition, ill temper, and nervousness. Walking for some people is a serious task. If there is proper training throughout life, walking may be more than a means of progression — it may be a real joy.

There are those who go to the other extreme as regards exercise. They strive constantly for records in athletic events. They over-develop their hearts, and serious harm often results. The danger for the nation, however, is not from athletics, but rather from a lack of all forms of physical education. It is to be remembered, therefore, that exercise is important, not only for the health of the individual, but also for the strength and vigor of the race. We have received our bodies as an inheritance from an ancestry that lived largely an outdoor life. To-day there is a great concentration of population in cities, and it is necessary that city

folk exercise out-of-doors to preserve the inheritance that has been received.

Forms of exercise. — It is best to choose a form of exercise that you enjoy. Exercise that is performed as a task is a drain on the nervous system; its results are questionable, and sooner or later it is given up in disgust. Too often the

FIG. 95. — Which is the better — forced exercise or games?

expression is heard, "I hate gymnasium work." This comes because the exercise is not interesting and in no way appeals to the instincts of the child. Most games and sports are excellent forms of exercise (Fig. 95).

The games that are most interesting are those that have the "give-and-take" principle present. Such games give to the player an opportunity and in turn take a chance.

This is illustrated in such a game as baseball. The pitcher gives the batter a chance at the ball and the batter takes the opportunity offered, or refuses it. Such games as swinging are less interesting because they have not this principle present. In which of the following games is this "give-and-take" element present and in which is it most prominent?

Tennis is a splendid game. It may be played in youth and in adult life by both sexes. It has a fine play element and gives good physiological results on the body.

Swimming is a very desirable form of exercise. Every city should have swimming pools, so that the sport may be practiced in winter as well as in summer. Sea bathing is very beneficial. To what is the beneficial effect chiefly due?

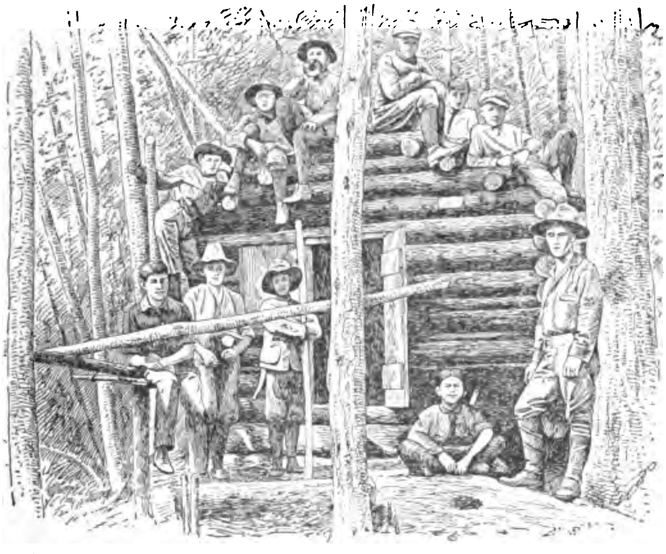


Fig. 96. — Cabin built by scouts for use as Troop Headquarters.

Camping. — The outdoor activities of the Boy Scouts, Girl Scouts, Camp Fire Girls, and other camping organizations afford a fine opportunity for outdoor exercise (Fig. 96).

The activities out-of-doors are especially beneficial upon the blood. For several years the author has kept a record of the increase in the iron content of the blood in girls in a summer camp. After six weeks of camping at Camp Mesacosa the average increase in hemoglobin has been 16 per cent. Some girls gained as much as 22 per cent. Good food, exercise, sleep and the sun's rays are the important factors in promoting this improved blood condition.

Walking and *running*, if not done too leisurely, are good exercises. Americans probably make too great a use of street cars. English women are noted as walkers, and in the cooler parts of the United States this custom would be equally effective in preventing nervousness and weakness among women. Walking requires proper shoes.

Running is a still better exercise, but it should be begun gradually and with caution, so as to give heart and lungs opportunity to become strong enough to sustain the increased effort required of them. One should never run with the mouth open. One should keep in such physical condition as at all times to be able to run swiftly and efficiently. Too frequently persons allow themselves to become so unfit that a run for 100 yards is impossible. To keep "fit" is at times difficult; it is always worth the effort.

Boxing and *wrestling* and *fencing* are good sports, but they are not common because of the skill necessary for their performance. They are more liable to produce injury of the participants and so should be well supervised. Boxing has become very popular in the training of the American army for the Great War. It provides not only the general beneficial effects of exercise, but the movements are similar in type and quality to the movements used in fighting with the bayonet. Every boy should develop skill in at least one of these three sports.

The group games such as volley ball, dodge ball, captain ball, and the group relays such as all-up relay, overhead

pass relay, and others are splendid games for the school ground and gymnasium (Fig. 97). The tug-of-war is excellent exercise (Fig. 98).

Fig. 97. — The relay race provides competition and demands coöperation. Notice the starting position of the girl on the right. Girls may learn to run freely as boys do.

The specialized games, such as *baseball, basketball,* and *football* are admirable during school days, but they are of

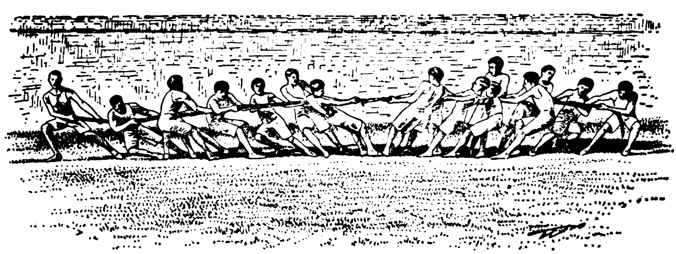


Fig 98. — Blind boys in a tug of war. Games and contests out of doors are available for all — even the blind.

little use after school days are over. Such games not only strengthen muscle and nerve but also may develop presence

of mind, coolness, fearlessness, self-control, and other fine qualities. Basketball with girls' rules, and indoor base-

FIG. 99. — Hockey requires strength and is valuable for the High School girl.

ball using the number 12 playground ball, are fine games for girls in high school and college.

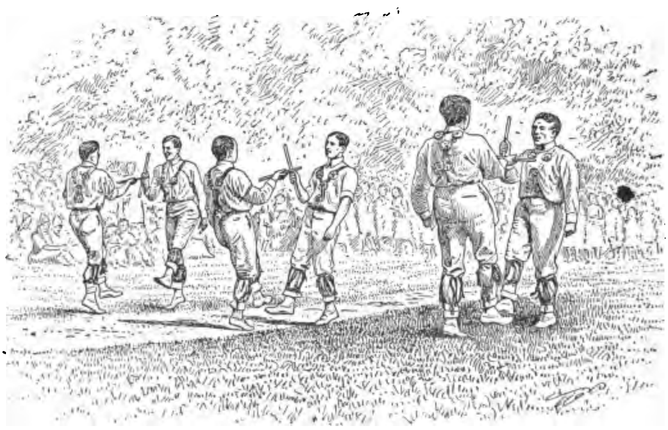


FIG. 100. — A Morris Dance. Men and boys do some dances better than women and girls. Dances of this type out of doors are not only healthful but also "fun to do." This kind of dancing calls for strength and endurance and may enlist the strongest athlete.

Hockey is a splendid game for girls. The field should be shortened to 70 yards, because the regulation field makes

too strenuous a game for girls, and, moreover, the shorter field permits more scoring and thus adds to the interest of the game.

Dancing. — The dance at one time was a ritual used in religious ceremonies. Dancing, therefore, really began as a religious cult. To-day there are different forms of danc-

FIG. 101. — Throwing the discus. The group in the background is holding a group baseball throw.

ing. Folk* dances are the dances of folk people giving expression to their feelings. These are dances, therefore, that are characteristic of the nations, and in this way we must think of the Tarantella of Spain, the Irish Lilt of Ireland and the English Country Dances. Æsthetic* dancing is an attempt to produce certain graceful forms of movement in dance. Too frequently, it is taught as a series of steps or poses in which there is no thought or emotion. It thus becomes a mere exercise. It should be taught as an art

in which all the technique serves as the medium for the self-expression of the dancer. Social dancing is in common use in the United States and eastern Europe. It is exhilarating and restful on account of the music and the rhythm. If it is done finely, in a beautiful way, it is very beneficial.

Athletic sports for girls need to have standards that are not too difficult for the girl athlete. Girls should not try to do the same events in which boys excel. There are, however, some athletic events that girls do very well, and two of these are shown in Figures 101, 102. In the figures showing the discus and lariat, notice that the left foot of the athlete is forward and the right arm. This opposite position of the arm and leg is very important in all throwing movements. For example, in throwing a baseball with the right arm, the left foot should be forward. Girls are familiar with this law in dancing, but because of their lack of training in sports

FIG. 102. — Throwing the lariat. This event calls for accurate judgment and good body.

they rarely show the good position of the discus thrower (Fig. 101). Camping with its related activities is very valuable for girls (Fig. 103). The following health essentials for

FIG. 103. — City girls on a "hike" in the country. Which one of the three girls shows the best posture?

girls 12 to 14 years old are good rules for all girls. The girl athlete could follow no better training schedule than this one, proposed by Dr. Thomas D. Wood.

SUGGESTED ESSENTIALS FOR HEALTH OF GIRLS 12 TO 14 YEARS OLD

1. Sleep. — 10½ hours in bed each night.
2. Food. — A nutritious diet with special emphasis upon an adequate breakfast.
3. Play and recreation. — At least one hour of out-door activity each day, during full daylight.
4. Bathing. — A tepid to cool sponge, shower, or quick plunge in the tub daily, before breakfast.
5. All the out-door air possible, particularly in the sleeping room.
6. Freedom from worry, hurry, and over-excitement.

The above schedule may serve with slight alteration as "training rules" for boys. The boy who is interested in athletics and physical efficiency will not use tobacco. More-

over, he should not spend more than three hours a day in practice. For many of the track sports, a half hour is sufficient. The high school boy is frequently injured in athletics by engaging in too many events in track meets, so that later, in college, he has not the endurance that he needs for sharper competition.

Over-development of muscles. — As important as muscular exercise is for sending the blood bounding through the veins and renewing the health of every part, exercise can be overdone. Some athletes develop great heavy muscles which are a burden to the vital organs to support. They do not take care to develop their lungs and breathing powers in proportion. Breathing exercises are often used to overcome the bad effects of inactivity and torpor. This method of getting strength and vigor is wrong. Exercise, vigorous enough to increase the respiration, should be used, and the breathing will care for itself. Those who aim only to develop certain muscles, who do nothing but apparatus work or some such specialty, get large muscles but not health and strength of body. Such athletes die young. Among those who have succumbed to consumption may be mentioned Kehoe, the famous club swinger; Dowd, the teacher of physical culture; "Jap," the wrestler; Winship, the inventor of the health lift; Kennedy, the strong man; and Peter Jackson, the pugilist. Complete living with conditions of health and activity for all the organs, without extreme use of any of them, is most conducive to a long and healthful life.

APPLIED PHYSIOLOGY

Exercise I

1. Does a few minutes' practice in a gymnasium suffice for a day's exercise?

2. Is there any relation between the amount of bodily exertion necessary for a person's health and the amount of wealth he possesses?

3. It is said that an Indian often runs or trots sixty miles per day, and that he rests his muscles without stopping by running for a while chiefly with the hip joint and muscles of the thigh, then with the knee joint and muscles of the upper leg. Can *you* rest some of the running muscles while running?

4. Can you relax the chewing muscles so that the lower jaw will swing loosely when the head is shaken?

5. Can you relax the muscles of the forearm so that the hand will shake loosely on the wrist and the fingers in their sockets?

6. Can you relax the whole arm so that another person can move it as a flexible rope?

7. Which joints of the limbs lock and refuse to bend further when the limb is straightened?

8. Which muscles have become useless with most persons, although some can still use them?

9. The average man has 60 lbs. of muscle and 2 lbs. of brain; one half of the blood goes through the muscles and one fifth goes through the brain. What inference may you draw as to the kind of life we should lead?

10. What are the beneficial effects of exercise upon the functions of the skin?

11. Is a slow formal walk suitable exercise? What exercise do you enjoy most? Do you practice it?

Exercise II

12. How can we best prove that we have admiration and respect for our wonderful bodies?

13. In what part of the skeleton is it most important to keep the muscular walls firm and strong in order to hold the internal organs in position?

14. Why should a youth who wishes to excel in athletic contests abstain from the use of tobacco?

15. How does the fact that if the nerves of one side of the face are paralyzed the face will be drawn toward the other, illustrate muscular tone?

16. Why does a game of baseball on Saturday afternoon actually rest a tired shop boy?

17. What movements did you ever see a cat go through for the sake of exercise?

18. What animals have you ever seen play? Stretch themselves for exercise?

19. Why do you feel so exhausted after a fright?

20. How do you account for the origin of the mental state, which holds in practice if not in theory, that all physical labor is an unmitigated evil?

21. Do you know persons who seem to be possessed by what is called " the spirit of jerkiness "? How could they overcome it?

22. What is energy? How is it formed?

LABORATORY EXERCISES

Experiment 1. To study the contraction of muscle.

Material.[1] — Muscle from a frog, muscle clamp, inductorium (Fig. 187), pincers, acetic acid.

Method and observation.

(*a*) Arrange the muscle from the frog's leg on a muscle clamp and keep the nerve intact. Pinch the end of the nerve and observe what happens to the muscle.

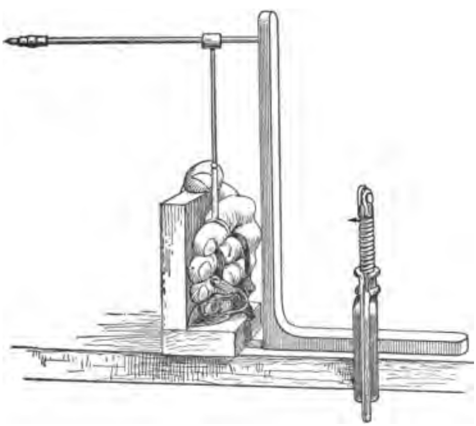


FIG. 104. — The ergograph; about one fifth the actual size.

(*b*) Touch the nerve with filter paper wet with the acetic acid. What happens?

(*c*) Place the electrodes of the inductorium on the nerve and stimulate with a "break" shock. (A break shock is produced when the circuit is broken by raising the key.) What happens when the nerve is stimulated?

Experiment 2. To study the effect of cold and heat on muscular contraction.

Material. — Hand dynamometer (this instrument may be borrowed from the physical education teacher), ice, and a large vessel.

[1] Apparatus for experiments in physiology may be obtained from the Harvard Apparatus Co., Back Bay station, Boston, Mass.

Method and observation. —

(*a*) Cool the hand and arm up to the elbow in ice water. This will cool the muscles which control the fingers. Make in three trials the maximal contraction on the dynamometer.

(*b*) Warm the hand and arm with heat and massage, and again make three trials on the dynamometer.

(*c*) Compare the results in (*a*) and (*b*). What do these results suggest for athletic activities and work in the gymnasium?

Experiment 3. To study the effect of exercise on size of muscle.

Material. — A non-stretchable and non-shrinkable tape.

Method and observation. — Measure the circumference (girth) of the biceps and triceps in the largest part of the upper arm. Write this measurement in your book and record the date. For a period of one month daily exercise the arm with dumbbells, chinning, or some other exercise which the physical education director will show you and again measure the arm in the largest part. How much has it increased in size?

Have the class tabulate on the board the gain and indicate the type of exercise chosen.

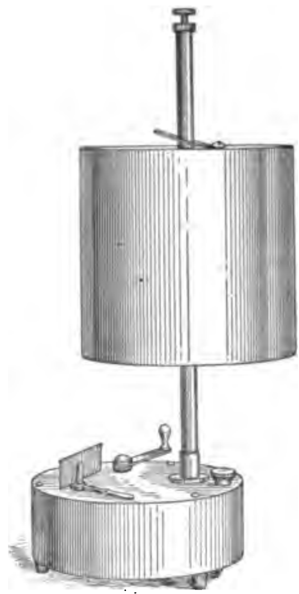


Fig. 105. — The kymograph and its aluminium drum; about one fifth the actual size.

Experiment 4. To study the effect of exercise on secretion of sweat.

(*a*) Swing Indian clubs for five minutes and note whether perspiration comes out on the face or body.

(*b*) After resting "run in place" for the same length of time and notice whether there is visible perspiration on the face or body. Why should there be this difference?

Experiment 5. To study muscular contraction and fatigue.

Material. — Ergograph (Fig. 104).

Method and observation. — Clamp the iron angle to a table (Fig. 104) and fasten the second, third, and fourth fingers to the wooden support. Upon the index finger, adjust the rod as shown

in the picture. Record the movement of the rod on a kymograph (Fig. 105). A highly glazed paper, smoked by a flame, is pasted on the drum to receive the tracing.

Does fatigue occur? To what is that due? Try the experiment after the day's work in school and before beginning the day. Do you notice any difference?

GLOSSARY

Æsthetic dancing. — A form of dancing that attempts to produce beautiful poses and movements. The movements are defined and exact and are *supposed* to cultivate grace and harmony in action.

Albumin. — A transparent, nitrogen-containing substance found in the blood and in many animal and vegetable juices and solids. It is a chief constituent of muscle. It has the very complex chemical formula ($C_{72}H_{112}N_{18}SO_{22}$).

Carbohydrate. — One of a group of chemical compounds containing carbon combined with oxygen and hydrogen in a definite way. The carbohydrates include the group of sugars represented by glucose ($C_6H_{12}O_6$), the double sugars, such as cane ($C_{12}H_{22}O_{11}$), and the starches, which are the simple sugars combined in large chemical masses $(C_6H_{10}O_5)_n$.

Coördination. — The act of harmonious motion so that parts are related to produce movements or actions that are not antagonistic.

Die Treppe. — A German word meaning the staircase. Used to describe the stairlike appearance of the graph made by a muscle when its contractions are recorded.

Dynamometer. — An instrument for measuring force or power exerted by the muscles in doing work.

Fat. — A greasy, easily melted, and soluble compound, forming a part of animal tissue and also found in plants. Fats consist of fatty acids such as palmitic, stearic, oleic, butyric, in combination with glycerin. The formula of butter, a common fat, is ($C_3H_5(C_4H_8O_2)_3$).

Fatty degeneration. — Cells of the body, especially muscle cells, may undergo degeneration. In the process, the characteristic structure of the cell is destroyed, and fat globules become deposited in the cell. Such a change in muscle is serious, because fat cannot do the work of the contractile fibers formerly present in the cell.

Folk dances. — Dancing that has been derived from the peasants of a nation, as a rule. The folk dance arose in a spontaneous way in an effort of the people to express their thoughts, feelings, and emotions.

Graphic representation. — To represent by writing, or recording.

Lung capacity. — The amount of air that can be breathed in by the greatest possible inspiration after the greatest possible expiration. It is measured by an instrument called the spirometer.

Narcotic. — A substance that produces depression of activity in the body. In large doses it may produce stupor and even death.

Protein. — A highly complex chemical compound containing carbon, hydrogen, oxygen, nitrogen, and often sulphur. It contains nitrogen, and so differs from fat and carbohydrate.

Psycho-motor. — A term that expresses the functioning of the neuro-muscular mechanism.

Voltaic cell. — A jar containing a liquid in which two metals are immersed and capable of producing electricity through chemical action.

CHAPTER IX

FOOD AND ITS ELEMENTS

I. Nutritive and Non-nutritive Elements in Food.
   - Protein
   - Carbohydrates
   - Fats
   - Water
   - Mineral matter
   - Table of food elements

II. Composition of Foods.

III. Sources of Food Elements.
   - Protein
   - Fats and oils
   - Carbohydrates

IV. Uses of Food in the Body.

V. Proportion of Food Elements in a Normal Diet.

VI. Calculation of Food Values.

VII. The Diet of Different Peoples.

VIII. The Body's Method of Regulating the Food Supply.

IX. The Work of Enzymes in Digestion.
   - Examples of enzyme action
   - Classification of enzymes

Nutritive and non-nutritive elements in food.— The food material used by man may be grouped under two heads, nutritive* and non-nutritive constituents. Nutritive elements are substances capable of combustion and the production of energy. Now, there are certain salts whose presence is necessary for life, but since they are not burned, they will be classed as non-nutritive. The nutritive substances are: (1) protein,[1] (2) fat, and (3) carbohydrate;

[1] The attempt a few years ago to secure the use of the German word "Proteid" for the nitrogen-containing foods was not successful, due largely

the non-nutritive are (1) water, (2) mineral matter, and (3) waste, such as bones, stones of fruit, cellulose.

Protein. — Protein is formed by living matter; it always contains nitrogen. There are definite proteins, such as albumin, hæmoglobin,* globulin,* etc. Protein is the great tissue-building material and consequently is very important in the diet during the period of growth.

Carbohydrates. (*Sugars and starches.*) — Why are roasting-ears sweet, although mature corn is not? It is because the sugar in the former has been changed to starch in the latter. On the other hand, ripe apples are sweet because the starch present when the apple is green has been changed to sugar. Starch and sugar are so nearly alike in composition and change so readily into each other, that as foods they are classed together.

The carbohydrates include sugars, starches, and gums, and form the principal element in vegetables. They are found in vegetables, nuts, fruits, grains, milk, and, to a slight extent, in meat and fish.

Fats. — The fats come from both animal and vegetable sources. Butter, cream, fat of meat, olive oil, and nuts provide the main supply of fat.

Water. — Water plays a very important part in the body by affording a medium for solution of the food elements after and during the digestive process.

Mineral matter. — There are in some proteins mineral elements in chemical combination. This does not prevent the classification of these as proteins, and in such cases the salt present may play an important part in combustion.

to the work of Halliburton and Hopkins. These physiologic chemists prepared a report on the use of the word "protein," and this report was adopted by a joint committee of the American Physiology Society and the American Society of Biological Chemists.

In this book, therefore, the word "protein" will be used to designate the nitrogen-containing foods, which consist so far as is known at present of α-amino acids and their derivatives.

In general we may say the mineral matter of food is not oxidized to produce heat. The minerals in combination with protein are known as organic minerals. There are inorganic minerals in the body, and they play, an important part in the transfer of substances from the blood to the tissues and of waste from the tissues to the blood.

Table of food elements.

Food stuffs	Nutritive	protein	nitrogenous
		fat	non-nitrogenous
		carbohydrate	
	Non-nutritive	water	
		mineral matter	
		waste	

The carbohydrates contain a greater amount of carbon than the proteins; remember, however, that proteins have some carbon.

Composition of foods. — Very few of the articles of food that we eat consist of only one of the classes of food elements mentioned; most foods consist of several elements combined. Oatmeal, for instance, contains starch, a small proportion of fat, a large proportion of protein, some mineral salts, and water. Let us see how the four classes are represented in milk. The part that makes it liquid is water, the sweetness comes from the sugar, the fat rises as cream, and the curd, from which cheese is made, contains casein,* a form of protein.

Sources of food elements. — All parts of plants may furnish food; the seed, as the various grains, nuts, and fruits; leaves, as lettuce, cabbage, dandelion; roots and tubers, as potatoes, beets, turnips, tapioca (root of cassava); stem, as sago (pith of sago palm); saps, as sugars (of cane, beets, and maple tree).

Protein. — Examples of proteins are: albumin, in white of egg; gluten,* the sticky or gluey part of grain; casein, in cheese and the curd of milk; fibrin, in the blood of animals;

myosin,* the basis of lean meat; gelatin, obtained from bones and ligaments by boiling; vegetable protein, in beans and peas; and the protein of nuts.

Fats and oils. — Fats and oils are found in: cream of milk, yolk of egg, oil of nuts, olives, cottonseed, cocoanut, and fat of meat.

Carbohydrates. — Carbohydrates are found (*a*) as starch in corn, wheat, rice, oats, and other grains, potatoes, cassava, arrowroot, sago (in this country the last two are usually potato starch sold under those names), beans, peas; (*b*) as sugar in sugar cane, sorghum, dates, honey (almost pure sugar), bananas (20 per cent), grapes, fruits, beets, maple sap.

Uses of food in the body. — Food has two uses in the body; first, to construct and repair tissues; and second, to produce energy for action. This action may be muscular action, which can be seen, or it may be nerve impulses or digestive process, the results of which only are seen. The tissue builders are protein food such as lean meat, eggs, milk, wheat, and vegetable proteins. This food may be used to produce energy if the fats and carbohydrates are insufficient in amount. The fats and carbohydrates furnish to a large extent the energy required. To some extent the fat of food may be stored in the body as fat, but only when taken in amounts above that required for producing energy. Fat in the body in large amounts is not desirable. There is no advantage and there is a distinct disadvantage in storing up a great excess of body fat. Such a condition is like putting money in the bank without receiving any interest on it. The mineral matter is absolutely essential in the formation of bone and in the internal transfer of substances. The usual mixed diet will provide with the exception of sodium chloride (common table salt) sufficient mineral matter for the body needs. From experiments it has been shown that alcohol is oxidized in the body, furnishing heat. On this basis it is

sometimes called a food. Under no conditions, however, does it serve to repair old or build new tissue. On the other hand, it is such a powerful drug, with such habit-forming and undesirable properties, that it is not to be considered as a desirable food.

Proportion of food elements in a normal diet. — Experience has shown that the diet best suited for the body should contain, besides water, protein one part, fat one to two parts, and carbohydrates three to four parts. It is conceded that people eat more protein than is necessary or desirable. Authorities differ in their recommendation, but it is quite generally held to-day that for the proper nourishment of the body the problem is — how much protein shall be used. There is substantial agreement as regards the energy foods: the fats, and the carbohydrates. The following dietaries* are recommended by Atwater and Voit:

Atwater's Standards	Protein Grams	Fat Grams	Carbohydrates Grams	Fuel Value Calories
Man at very hard muscular work	161			5500
Man at hard muscular work . .	138			4150
Man at moderate muscular work	115			3400
Man at light to moderate muscular work	103			3050
Man at sedentary or woman at moderate work	92			2700
Woman at light muscular work .	83			2450

Voit's Standards	Protein Grams	Fat Grams	Carbohydrates Grams	Fuel Value Calories
Man at hard work	133	95	437	3270
Man at moderate work	109	53	485	2965

It will be noticed that in Atwater's table the amount of energy foods is omitted. The amount of fat or carbohy-

drate may vary as long as the total amount of both is sufficient, together with the protein, to supply the required energy. From the table of food values on page 153 select sufficient amounts of fats and carbohydrates to yield, together with the protein, the calories* as given in the last column in Atwater's Standards.

Other authorities recommend a lower protein intake. During the first year of the Great War, Thompson and Ballod investigated the food consumption of Great Britain. According to Thompson, a British physiologist, the protein intake per day was 2.70 ounces (1 ounce = 31.1 grams); estimate of Ballod, a German statistician, was 3.75 ounces. Both estimates are considerably lower than the protein proportion given by Voit or Atwater. Professor Chittenden of Yale University has shown that health may be maintained, for a long period, with a protein intake as low as 50 grams per day. The experience of the German people has apparently proved the validity of the lower figure for protein. It may be stated, therefore, that the protein intake daily need not exceed 100 grams.

Calculation of food values. — Food is of use in the body because on oxidizing it produces heat. The heat energy of food is measured in terms of the great calorie, and a great calorie [1] is defined as that amount of heat necessary to raise one kilogram of water from 0° to 1° C, or one pint about 4° F. By experiment it has been found that the following is the caloric value of the three food elements:

1 gram of protein yields 4.1 calories
1 gram of fat yields 9.3 calories
1 gram of carbohydrate yields 4.1 calories

Now the number of calories required varies with the size of the individual, the character and amount of work, and the

[1] This is the Great Calorie. The small calorie is the amount of heat required to raise one gram of water one degree C.

condition of health. Langworthy follows Atwater's Standards and gives the following requirements:

Man doing no muscular work . . .	2450 calories a day
Man doing light muscular work . .	2700 calories a day
Man doing light to moderate muscular work	3050 calories a day
Man doing moderate muscular work	3400 calories a day
Man doing very hard muscular work	5500 calories a day

Lumbermen working during the winter months in the Maine woods consume food in a single day that yields 8000 calories. The average man should use about 3000 calories and this will be obtained by taking in a day 100 grams of protein, 150 grams of fat, and 350 grams of carbohydrate. Brain workers do not need so many calories as laborers in the field or factory. There is no particular kind of food that will serve as "brain food," although fish and certain prepared foods are often claimed to have that virtue.

The caloric needs of an individual form the basis for determining the food needs of a nation. It is with scientific exactness, therefore, that the Belgian Relief Commission calculated, "until after the harvest of 1919 it must feed ten million people in Belgium and Northeastern France. They will require, in twelve months, forty-two million bushels of breadstuffs and over three hundred million pounds of meat; the children alone must have seventy-three million pounds of condensed milk and cocoa and forty million pounds of sugar."

The study of the following table,[1] arranged from Locke, will show the quantity and the caloric value of different foods. Select from this table and write on the blackboard the articles and quantity which will be necessary to provide, approximately, 100 grams of protein, 150 grams of fat, and 350 grams of carbohydrate. Compute the caloric value. In some cases it will be desirable to select two portions of the food.

[1] Selected from Food Values by Edwin A. Locke
h. tbs. = heaping tablespoonful
h. ts. = heaping teaspoonful

Food	Quantity of Food	Weight of Quantity in Grams	Water in Food in Grams	Protein		Fat		Carbohydrate		Calories per 100 Grams	Total Caloric Value of Amount Selected
				Grams of Protein	Caloric Value of Protein	Grams of Fat	Caloric Value of Fat	Grams of Carbohydrate	Caloric Value of Carbohydrate		
Roast beef . .	1 slice	100	48.20	22.30	91.4	28.6	266	—	—	357	357
Roast lamb .	1 slice	175	50.33	14.78	60.6	9.53	88.6	—	—	200	150
Mutton chop .	1 chop	100	71.80	22.60	92.7	4.5	41.9	—	—	135	135
Fried ham . .	1 slice	35	12.81	7.77	31.9	11.62	108.1	—	—	400	140
Butter . . .	1 ball	15	1.65	0.15	0.6	12.75	118.6	—	—	795	119
Cheese (Amer.)	1 cu. in.	20	6.32	5.70	23.6	7.18	66.7	0.6	.2	453	91
Milk (whole) .	1 glass	220	191.40	7.26	29.8	8.80	21.8	11	45.1	72	157
Egg (boiled) .	1 egg	50	36.60	6.60	27.1	6	55.8	—	—	169	83
Baked beans .	3 h. tbs.	150	91.17	10.83	44.4	12.76	118.7	32.84	134.6	199	298
Carrots . . .	3 h. tbs.	100	93.40	.53	2.2	.17	1.6	3.39	13.9	18	18
Corn (green) .	1 ear	100	72.6	3.07	12.6	1.10	10.2	18.78	77	100	100
Peas (green) .	3 h. tbs.	92	67.90	6.16	25.3	3.13	29.11	3.43	55.1	119	110
Potato (baked)	1 med.	130	90.87	3.77	15.5	.20	1.9	32.07	131.5	114	149
Apple . . .	av. size	150	94.90	.45	1.8	.45	4.2	16.2	66.4	49	72
Orange . . .	av. size	250	158.5	1.5	6.2	.25	2.3	21.25	87.1	37	96
Marmalade .	1 h. tbs.	30	4.35	.18	.7	.03	.3	25.35	103.9	349	105
Bread (white)	1 slice	30	10.59	2.76	11.3	.39	3.6	15.93	65.3	268	80
Bread (whole wheat) . .	1 slice	42	16.13	4.07	16.7	.38	3.5	20.87	85.6	251	106
Crackers (graham) .	1 cracker	8	.43	.80	3.3	.75	7.0	5.90	24.2	429	34
Ham sandwich	1 sand.	70	24.15	7.28	29.8	10.07	93.7	26.65	109.3	332	233
Oatmeal . .	2 h. tbs.	100	84.50	2.80	11.5	.50	4.7	11.50	47.2	63	63
Rice (boiled) .	1 h. tbs.	100	72.50	2.80	11.5	.10	.9	24.40	100	112	112
Shredded wheat bis. .	1 biscuit	29	2.35	3.05	12.5	.41	3.8	22.59	92.6	375	109
Spaghetti . .	3 h. tbs.	145	111.21	4.52	18.5	2.81	26.1	25.76	105.6	103	150
Cake choc. . .	av. slice	70	14.30	4.34	17.8	5.67	52.7	44.87	184	364	255
Sugar cookies .	1 cooky	11	.91	.77	3.2	1.12	10.4	8.05	33	423	47
Granulated sugar . . .	1 h. ts.	10	—	—	—	—	—	10	41	410	41

The diet of different peoples. — Milk has an excess of nitrogen, and oatmeal an excess of carbon; oatmeal and milk form a perfect food, and it is not surprising that the Scotch people, with whom it has been a chief food, are a sturdy race. Potatoes are mostly starch and water; the starch in them is nearly nine times as much as the protein, and an Irishman who tried to live on potatoes alone would have to eat seven pounds a day to get enough protein. By

eating milk and eggs also, he can get along on half the amount of potatoes named above. Every Irish peasant is said to keep a cow and chickens. The Mexicans eat bread made of corn meal, and supply the protein by using beans as a constant article of diet. The Zulus live on cracked corn by adding milk to it. The Arabs live on barley and camels' milk, rarely eating the camels' flesh. Hundreds of millions of people in Asia (the Hindoos, Chinese, and others) subsist mainly on rice, which is more nearly pure starch than any of the grains, containing only 6 per cent of protein, about half as much as wheat and corn; the chief addition they make is butter or other fat, and beans, which contain vegetable protein. Their meager diet may partly account for their lack of energy and bravery, and the ease with which they are conquered and controlled by European nations. The greatness of a people is greatly influenced by their diet.

The body's method of regulating the food supply. — We should not think that the food eaten must be regulated with the greatest precision. Any reasonable excess will pass through the canal unabsorbed, without great injury to the body. The lack of any of the necessary elements will be well tolerated for a time until a craving for a certain kind of food will lead later to the supply of the elements needed. If a person feels bad, or the digestion seems weak, some will advise dieting. There is a tendency among certain writers on hygiene to overrate the importance of this subject. If the laws of health in regard to fresh air, muscular exercise, sleep, cleanliness, temperature, and abstinence from the use of stimulants be observed, our appetites usually will be a sufficient guide in the matter of diet. These matters should first be looked to, and dieting then will probably become unnecessary.

It is an instructive and important fact, that too much consciousness of what is eaten and too much dwelling on what might be the consequence of eating this food or that

food, may interfere seriously with good digestion. If the sense of taste is not abused, but its promptings treated with great respect, we shall preserve a useful guide which will tell us more perfectly what is needed than any scientific table can do. Food that brings discomfort after eating, however, should not be eaten.

The work of enzymes* in digestion. — The preparation of food in the body so that it can be assimilated (taken up by the cells) is a process in which certain digestive juices act upon the food mass. The action of these juices is effective because they contain substances which break up the food masses into smaller units. This breaking up is accomplished by bodies known as *enzymes.* It is important to understand what their nature is.

Example of enzyme action. — The souring of milk, the putrefaction* of animal substances, and the fermentation of food materials have been explained in various ways in past years. These phenomena led to investigations, and it was learned that the chemical action going on differed from other chemical action in that the substance producing the change was not destroyed or used up in the reaction. Pasteur showed that fermentations were due to bacterial action. It was later learned that there were other substances produced by living cells which would cause changes in food. These substances are known as enzymes. They have special names, for example, the enzyme of the saliva is ptyalin, of the gastric juice, pepsin and rennin, of the pancreatic juice, trypsinogen, lipase, etc. Enzymes act to produce a chemical change, but they themselves do not enter into the reaction. What is catalysis* in chemistry? Are enzymes similar to catalyzers?

The action of the enzyme is always specific. The ptyalin of the saliva changes starch to sugar, but it has no effect on protein. Each enzyme acts on a particular kind of food material; it is fitted to it " as a key to its lock."

Classification of enzymes. — If digestion is thought of as a process similar to the work of a stone cutter, who takes a rough mass of stone and cuts it up into blocks of a certain size to fit into a particular place in the building, then the action of enzymes may be likened to the chisels which break the stone. This breaking down of food compounds into smaller units is called " splitting," and so we speak of protein-splitting enzymes, fat-splitting enzymes, etc.

1. Protein-splitting enzymes. — Pepsin (gastric juice) and trypsinogen (pancreatic juice). They cause in a reaction with water a splitting of the protein into smaller units capable of absorption by the body cells. This action with water is called hydrolysis.*

2. Starch-splitting enzymes. — Ptyalin (saliva) and amylase (pancreatic juice). The action in this case is one of hydrolysis. The starch molecule is converted into a less complex one, a sugar, in the form of two molecules of sugar (disacchride).

3. Sugar-splitting enzymes. — These split the disacchrides into monosacchrides. Examples, maltase, which converts maltose into two molecules of dextrose; invertase, which splits cane sugar into dextrose and levulose; and lactase, which splits milk sugar into dextrose and galactose. The following formula * indicates what this change is:

$$\underset{\text{maltose}}{C_{12}H_{22}O_{11}} + \underset{\text{water}}{H_2O} + \underset{\text{enzyme}}{\text{maltase}} = \underset{\text{dextrose}}{C_6H_{12}O_6} + \underset{\text{dextrose}}{C_6H_{12}O_6} + \underset{\text{enzyme}}{\text{maltase}}$$

The enzyme maltase causes the change; it is not destroyed or used up in the process.

4. Fat-splitting enzymes. — Lipase (pancreatic juice and bile). This acts by hydrolysis; as,

$$\underset{\text{Tristearin}}{C_3H_5(C_{18}H_{35}O_2)_3} + \underset{\text{water}}{3H_2O} + \underset{\text{enzyme}}{\text{lipase}} = \underset{\text{glycerin}}{C_3H_5(OH)_3} + \underset{\text{stearic acid}}{3(C_{18}H_{36}O_2)} + \underset{\text{enzyme}}{\text{lipase}}$$

The fat mass tristearin found in beef fat is broken down into glycerin and stearic acid.

GLOSSARY

Albuminoid. — Substance similar in composition to albumin.

Calorie. — Food when it undergoes combustion produces heat. This heat is measured by standards and the unit of heat used as the standard is the calorie. The greater calorie is the amount of heat required to raise one kilogram of water one degree C. When speaking of the caloric value of food, it is the greater calorie that is meant.

Casein. — The name of the protein of milk after it has been coagulated by the enzyme rennin. Before coagulation, the protein is called caseinogen.

Catalysis. — A chemical change brought about in a chemical compound by an agent that does not enter into the action of the change in a chemical way.

Dietary. — A systematic arrangement of the diet.

Enzyme. — A substance that induces digestive chemical action in the food elements but does not enter itself into the chemical change. The ptyalin of the saliva is an enzyme.

Formula. — A group of symbols showing the composition or structure of a chemical compound.

Gelatinoid. — A substance similar in composition to gelatin.

Globulin. — One of the proteins. The chief globulins in the body are serum globulin and fibrinogen of the blood, myosinogen of muscle, and globin in combination with hematin in the red corpuscle.

Gluten. — An essential element in the cereal wheat. It gives to the flour important nourishing characteristics. It is a protein.

Hæmoglobin. — The iron-containing substance in the red corpuscle. Chiefly noted for its ability to carry oxygen in chemical combination. It is formed from a globulin, globin, and an iron radical called hematin.

Hydrolysis. — The chemical decomposition of a compound that ensues when water (H_2O) is absorbed by it.

Myosin. — Formed from myosinogen. It comprises 75 per cent of the protoplasm of muscle tissue. It is a protein. At death it coagulates, and causes *rigor mortis*.

Nutritive. — Having properties which promote nutrition.

Putrefaction. — The act of breaking down of an organic compound It represents decay and decomposition.

CHAPTER X

THE DIGESTION OF FOOD

I. The Structure and Functions of the Alimentary Canal.
 The mouth
 The pharynx
 The esophagus
 The stomach
 The small intestine
 The large intestine
II. The Liver.
 Anatomy
 Functions
III. Diagram of Digestive Mechanism.
IV. The Waste Products from Food Elements.

The structure and functions of the alimentary canal. — Food, in order to be of service to the body, must undergo several changes. Its nutritive portion must be separated from the non-nutritive; and the former must be made soluble, or in fit condition to be taken up by the blood and carried to the tissues. This process is called digestion, and the assemblage of organs by which it is carried on is called the digestive system. The tube which forms the receptacle for the food during digestion is called the alimentary * canal. In the carnivora, or flesh-eating animals, whose food contains but a small amount of indigestible matter, the alimentary canal is comparatively short, being, when stretched out, only three or four times the length of the body. In the herbivora, or grass-eating animals, the canal is thirty times the length of the body. In the hog, which is omnivorous

("all-eating"), it is ten times the length of the body. If man's trunk only is counted, the canal is twelve times as long; if his height is counted, the canal is six times as long.

The alimentary canal has three coats in its walls throughout its whole length. What is each for? The inner coat, or lining, is a delicate epithelial tissue called the mucous membrane. It forms a smooth lining to prevent friction, and secretes a mucus which serves the same purpose. The next coat is the submucous coat; it is of elastic connective tissue, and serves to toughen and strengthen the wall, and to bind the mucous coat to the muscular coat. Outside of this is the third coat. It is composed of several layers of involuntary muscular tissue, which, by its contraction, causes the food to move along the canal (Fig. 114).

In the walls of the alimentary canal are numerous blood vessels and lymphatics. Opening on its inner surface are mouths of ducts from the various glands of the digestive system. Some of the glands are of considerable size and lie outside of the canal; others are very minute and are embedded in the walls of the canal; their secretions render the food soluble.

When we swallow food or drink, we are accustomed to say that it is in the body, but anatomically and physiologically this is not correct. It is on the outside anatomically, because the mucous membrane is continuous with the skin, which is the external covering (Fig. 106). It is on the outside physiologically, because the food must pass through the mucous membrane before it can be assimilated by the tissues and become of use to the body.

A lean person often eats a great deal, expecting to get fat, and finds that, although he has swallowed the food, the nourishment has never really entered his body.

The mouth. — The food is held in the mouth for a short time while it is mixed with the watery alkaline fluid called the saliva, and is ground up fine by the teeth. The partition

between the nose and the mouth is formed by the palate bones, covered with mucous membrane. The larger part of the roof of the mouth is formed by these bones and is called the hard palate. The roof is completed in the rear by the fleshy soft palate. The floor of the mouth is occupied

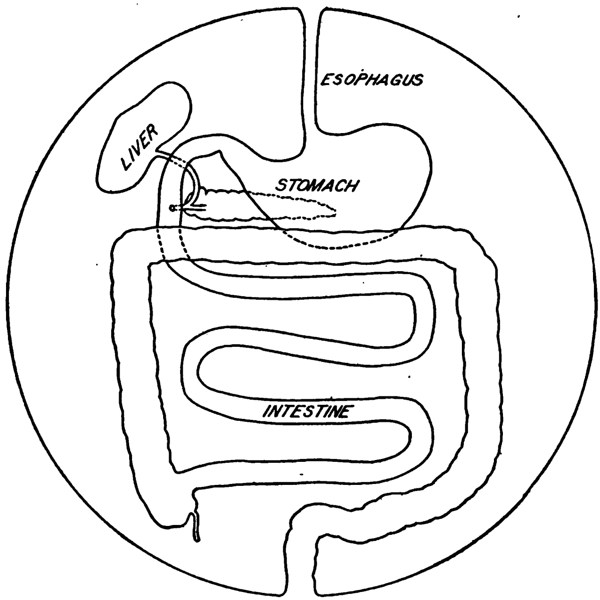


FIG. 106. — The food materials must pass the mucous membrane lining of the alimentary tract before they are *within* the body. The liver is displaced upward to show the parts under it.

mostly by the tongue; the lips form the front wall, and the cheeks the side walls. The cheek is composed partly of a large flat muscle called the buccinator (*trumpeter*, because used in blowing a trumpet). The contraction of the trumpeter muscles, together with the movements of that flat muscle called the tongue, keeps the food between the teeth in the act of chewing, or mastication.

Salivary Glands. — There are three pairs of glands that

secrete saliva. In structure one of these glands with its duct resembles a minute bunch of grapes with a hollow stem. The largest, called the parotid, is just beneath the skin in front of the ear. Its duct opens into the mouth in the upper jaw opposite the second molar tooth. This gland swells in a disease called the mumps. The next largest gland is the submaxillary, lying within the angle of the lower jaw. Its duct opens into the floor of the mouth. The smallest, the sublingual, lies farther to the front; both glands of the pair lie beneath the tongue, and open by a number of ducts. The fluid produced by these glands becomes mixed with the mucus from the mucous membrane of the mouth and is called the saliva.

Saliva. — Saliva is a thin, colorless, alkaline liquid, slightly sticky, and often containing air bubbles. The digestive enzyme of the saliva is ptyalin, which has the power to

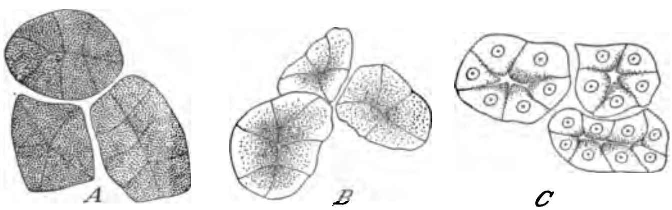


FIG. 107. — Cells of the salivary gland. *A*, after rest; *B*, after a short period of activity; *C*, after a prolonged period of activity. Shriveling and loss of granules occur.

change starch to malt sugar. Maltase is also present which changes the malt sugar to dextrose. From one to three pints of saliva are produced daily (Fig. 107). Its flow is excited by the act of chewing and by anything held in the mouth, especially if it be of an agreeable taste or odor. Hunger, or the sight or thought of agreeable food, makes the "mouth water" by stimulating the cells in the glands to activity by means of the nerves. But by far the most powerful of all the excitants to the salivary flow is dryness

of the food. Only one fourth as much saliva is deposited in the same length of time when eating oatmeal and milk as when eating crackers or dry toast.

The Tonsils. — The tonsils * (Fig. 108) are large lymph glands. They are oval in shape but vary greatly in size in different people. They become infected frequently and cause in this way many cases of heart disease and rheumatism. * Many people who suffer from rheumatism could be cured by proper treatment of infection existing in the tonsils or teeth. The tonsils can be removed entirely without injury to the health, and if they are diseased, removal of them will improve the health.

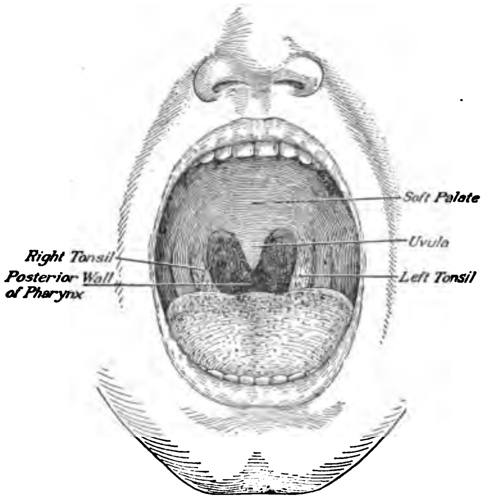


Fig. 108. — Structures within the mouth as seen when it is open and tongue depressed. (Modified after Coakley.)

The use of tobacco is a common cause of diseases of the throat. It causes a dryness and thirst, and frequently leads those who use it to take alcoholic drinks. Often the habit of smoking produces a troublesome disease called smokers' sore throat, which can be cured only after smoking has been discontinued. The heat of smoking is very trying to the organs, although not so injurious to them as the poison of the tobacco.

Absorption * from the Mouth. — The passage of digested food into the blood vessels is an important sequel of the

digestive process. A little of the water containing sugar and salts is absorbed from the mouth directly into the blood vessels. Poisonous substances may sometimes be absorbed from the mouth in sufficient quantities to produce death. If a drop or two of prussic acid should be placed on the tongue or on the mucous membrane of the mouth, death would occur in a few minutes, although not a particle of it had reached the stomach. Boys who take their first chew of tobacco learn in a disagreeable way that the entire body may be affected by absorption from the mouth. The absorption of food in the mouth is insignificant in amount compared to the absorption that takes place in the small intestine.

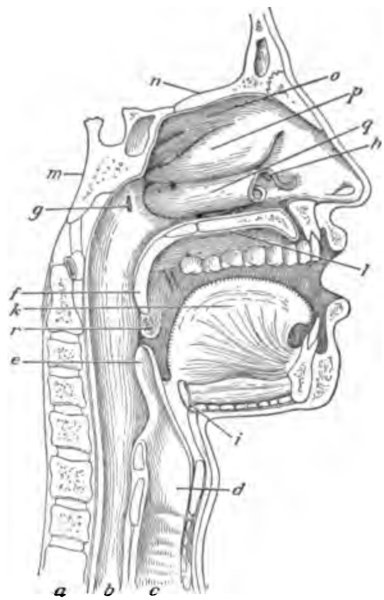


FIG. 109. — Mouth and upper part of esophagus (see Plate VII). *a*, vertebral column; *b*, esophagus; *c*, trachea; *d*, larynx; *e*, epiglottis; *f*, soft palate and uvula; *g*, opening of left Eustachian tube; *h*, opening of left lachrymal duct; *i*, hyoid bone; *k*, tongue; *l*, hard palate; *m*, *n*, base of skull; *o*, *p*, *q*, the scroll-like or turbinated bones; *r*, tonsil.

*The pharynx** (far′inks). — A muscular bag opening from the nose and mouth, four and a half inches in length, lies against the spinal column. It is commonly called the throat. There is an air passage from nose to lungs and a food passage from mouth to stomach. They cross each other, and the intersection is called the pharynx. There are seven openings from the pharynx: one to the mouth, one below the mouth into the trachea, one behind the trachea into the

esophagus, and two pairs of openings in the upper pharynx; one of these pairs is to the nasal passages, and the other pair is into the Eustachian tubes, which lead to the ears. When swallowing, all of the openings close but the one to the mouth and the one to the esophagus. (See Plate VII.)

The upper part of the pharynx, and thus the openings to the nose and ears, can be closed by raising the tip of the soft palate, or uvula,* against the back wall of the pharynx (Fig. 109). Sudden laughter or coughing while swallowing may cause the soft palate to relax, and then a portion of the food or drink is sometimes forced into the nose. The opening to the trachea can be closed in two ways: by the vocal cords contracting and approaching one another; or by the drawing upward of the larynx to the epiglottis.* The opening from the mouth, called the fauces, can be closed by the contraction of upright muscles, called the pillars of the fauces, which connect the posterior part of the soft palate and the base of the tongue. These muscles come together in the middle like sliding doors. There are two of them on each side, and the tonsils lie between them (Fig. 108). The tip of the soft palate hangs down between the pillars, and is called the uvula. By looking into a mirror with the mouth very wide open and the tongue flattened, you can

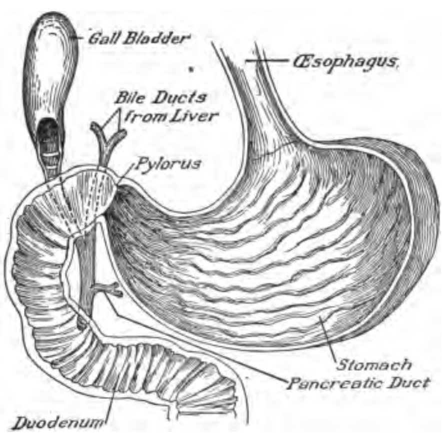


FIG. 110. — The stomach, duodenum, and gall bladder laid open. When digestion is completed the bile from the liver backs up into the gall bladder.

see the palates, the pillars, the uvula, and perhaps the tonsils.

The esophagus. — The esophagus, which conducts the food to the stomach (Figs. 109, 110), opens from the lower part of the pharynx. It is about nine inches long, and lies in front of the spinal column and behind the trachea. It has the three layers found elsewhere in the alimentary canal, and its walls are soft and lie collapsed when no food or drink is passing. The food is under reflex control after passing the fauces. The contraction of the pharynx presses the food down into the esophagus. A ring of the muscular tube contracts just above the morsel. This contraction runs down to the stomach, forcing the food before it as if a tight ring were slipped down over the esophagus. A contraction of any part of the alimentary canal in this manner, as if a wave were traveling along, is called a peristalsis.* While a horse is drinking, the peristaltic waves of the esophagus may be plainly seen along the neck (Plate V).

The stomach. — The esophagus pierces the diaphragm to the left of the center and enlarges into a pouch called the stomach. This organ lies just under the diaphragm, mostly on the left side of the abdomen and half covered by the lower ribs. It is capable of holding about two quarts. When full, it is about a foot long and five inches broad. Its shape is not easily described (Fig. 110). It is placed across the abdomen, and its left end is the larger. Its outline is curved inward above and outward below. When empty, it flattens and its walls touch, and the mucous lining then lies in deep wrinkles or folds. The opening where the esophagus ends, and through which the food enters, is called the cardia, because it is near the heart. The opening where the intestines begin, and through which the food leaves, is called the pylorus* (gate keeper); both openings can be closed by circular muscles in their walls.

Movements. — Anything taken into the stomach causes *peristalsis*. The food is caused to go from the esophagus to the left of the cardiac orifice, then down to the right and back again, the circuit from left to right, then from right to left, taking from one to three minutes according to the activity of the peristalsis. The muscular fibers in the walls of the stomach are in three layers (Fig. 111); one layer runs lengthwise, another around, and the third obliquely, so that the varied contractions cause the food to become thoroughly mixed with the digestive juice.

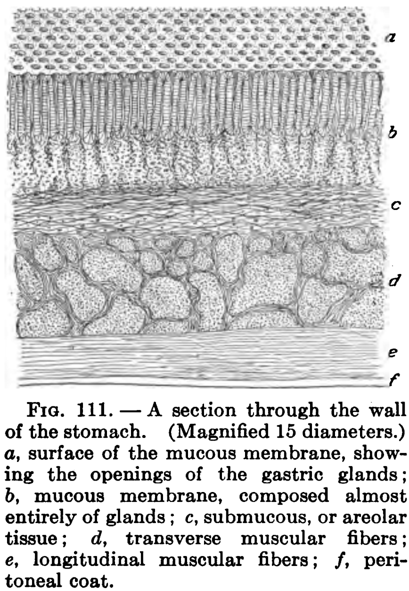


FIG. 111. — A section through the wall of the stomach. (Magnified 15 diameters.) *a*, surface of the mucous membrane, showing the openings of the gastric glands; *b*, mucous membrane, composed almost entirely of glands; *c*, submucous, or areolar tissue; *d*, transverse muscular fibers; *e*, longitudinal muscular fibers; *f*, peritoneal coat.

Secretion. — The secretion of the stomach is called gastric juice. This is a yellowish fluid and consists of water having in solution hydrochloric* acid and two enzymes. These remarkable substances, although existing in very small quantities, are able to change the composition of large quantities of food. In times of rest, when there is no food present, the mucous membrane of the stomach is of a pale red color. But when food is introduced, a change at once takes place. The membrane becomes charged with blood and consequently turns to a deep red color. The gastric juice, secreted by many small glands (Fig. 112), appears on the walls of the stomach, and peristaltic action begins.

One enzyme of the gastric juice, called rennin, acts by

coagulating milk, a change somewhat like the coagulation of the blood. It causes coagulation by acting upon the protein part of the milk. It is especially abundant in childhood. The other enzyme, called pepsin, softens the protein part of food and reduces it to peptone, in which form it is soluble in water. Pepsin, however, can act only when the hydrochloric acid has accumulated to an amount sufficient to neutralize* the alkaline condition caused by the saliva. This usually requires about thirty or forty minutes. The hydrochloric acid, by its presence in sufficient quantity, not only enables the pepsin to act, but also prevents fermentation of the food and kills all germs that may enter the stomach.

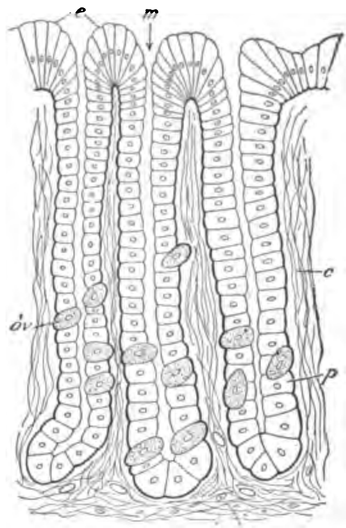


FIG. 112. — Three glands of the stomach. *e*, epithelium at inner surface of stomach; *m*, mouth of gland; *p*, principal cells of gland; *ov*, ovoid cells; *c*, connective tissue below and between the glands.

The saliva continues its work even in the stomach until neutralized by the acid. The pepsin then begins to act. The outside of the food particles is acted upon first, and this digested part is then rubbed off by the peristaltic movements, and the next layer is acted upon. Its action is confined to the protein. In fat meat the albuminous walls of the cells are eaten away and the fat is set free but not digested. Starch may also be set free from albuminous envelopes. The food is thus reduced to a semifluid condition and is called chyme.*

After the food has been reduced to chyme, the pylorus

opens every minute or two, permitting a little of the chyme to escape into the intestine. But if some hard object, as a button, or a lump of raw starch from an unripe apple insufficiently masticated, enters the stomach, the pylorus, after a while, will become fatigued and will relax and allow it to pass without becoming semifluid.

Action of the Acid Chyme. — As the acid chyme passes into the duodenum it causes an important chemical action. When the acid chyme comes in contact with the mucous membrane of the intestinal wall some of it is absorbed, and this, acting on an enzyme (prosecretin) in the intestinal cells, causes the formation of another enzyme, secretin. The secretin passes into the blood and, coming to the liver, pancreas, and cells of the intestinal walls, causes these organs to pour out their digestive juices. For many years it was not understood how the pancreas or liver could know when to free their digestive juices, because the food did not come in direct contact with their cells. It is the secretin, therefore, which tells these organs when they must give up their juices for digestive purposes. The secretin causes the flow of the pancreatic juice, the bile, and the intestinal juice (page 184).

Absorption from the Stomach. — A slight absorption may take place in the stomach of a portion of the protein digested there. Some of the sugar resulting from the salivary digestion of starch by the saliva may also be absorbed. Nearly all the absorption of the food takes place in the small intestine, and it is there likewise that most of the digestion occurs; for, upon leaving the stomach, the greater part of the protein, carbohydrates, and all the fats and oils, remain to be acted upon.

The Stomach as a Storehouse. — It is a common notion that digestion is carried on chiefly in the stomach. Some physiologists give tables stating that pork requires five hours for digestion, fried beef four hours, roasted beef three hours, apples one hour, etc.; what is meant is that it requires that

length of time for these foods to leave the stomach, the digestion being far from complete. Investigation in the last few years shows that the stomach is a kind of storeroom or antechamber in which food is stored, being softened and kept free from germs and gradually delivered to the intestine.

Of the thirty or more feet of the alimentary canal, the food, upon leaving the stomach, has traversed about two feet. Of the fourteen hours required for digestion, about three or four hours have passed. A portion of the starch and protein has been digested and a small amount of each absorbed by the blood vessels. The fats have not yet been acted upon.

It is essential that the part performed by each prior organ should be well performed, for this determines whether the changes in the food in the next organ shall be easily and completely accomplished. If the food is thoroughly masticated in the mouth and the saliva well mixed with it, this alkaline condition excites the flow of the acid gastric juice, which otherwise would be scanty. If the gastric juice is strong and acts freely upon the food, the acidity of the food as it leaves the stomach and enters the small intestine excites the flow of the alkaline intestinal juices.

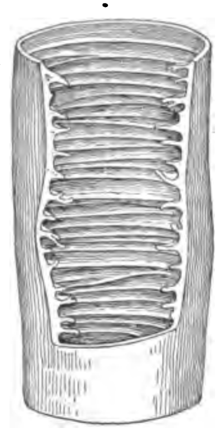


FIG. 113. — A portion of small intestine cut open to show the folds on its inner surface.

The small intestine. — When the chyme passes the pylorus, it enters the small intestine, which is a tube about as large around as the thumb, and about twenty feet long, lying coiled in the central part of the abdominal cavity. The first part of it, about ten inches in length, is called the duodenum (from a word meaning twelve, because its length is twelve fingers' breadth). The mucous and submucous coats of the small intestine are wrinkled by

numerous folds which are crescent-shaped, since no single fold goes entirely around the tube (Fig. 113). The folds are so numerous that they occupy almost the entire inner surface. The small intestine is the chief organ of absorption as well as of digestion, and the absorbing surface is greatly increased by the folds. On and between the wrinkles are innumerable tiny projections called villi * (Fig. 114). Each villus contains a loop of blood vessel and a very small lymphatic called a lacteal. Since the villi are so thickly placed as to cover the entire mucous coat of the intestine like the pile on a piece of velvet, the absorbing surface is enormously increased.

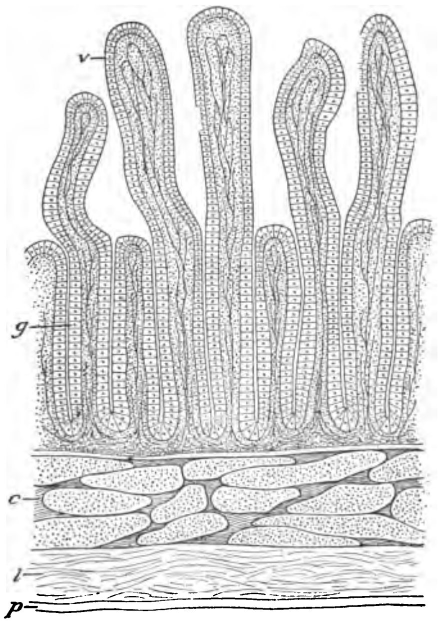


FIG. 114. — To show the structure of the wall of the small intestine. *v*, villi, and *g*, glands of the mucous membrane; *c*, circular muscle layer; *l*, longitudinal muscle layer; *p*, peritoneum, or serous coat.

The Support of the Intestine. — The abdominal cavity, or the portion of the large cavity of the trunk below the diaphragm, has, like the thoracic cavity, a lining to prevent friction. This membranous lining is called the peritoneum, and like the pleura, it is double. It covers up the wall of the cavity all around, lining it like a thin sheet, until it reaches the place under the diaphragm where the esophagus

and larger blood vessels (aorta and vena cava) enter, where it is reflected and courses downward, enveloping the stomach and other digestive organs. It penetrates between them by means of foldings and turnings, thus assisting to hold them in place. The largest fold of all is called the great omentum and covers the small intestine. The peritoneum surrounding the intestines is called the mesentery. It is fan-shaped and its contracted part is attached to the spinal column for a firm support. The alimentary canal, beginning with the stomach, may be said, therefore, to have a fourth layer, or covering, the peritoneum.

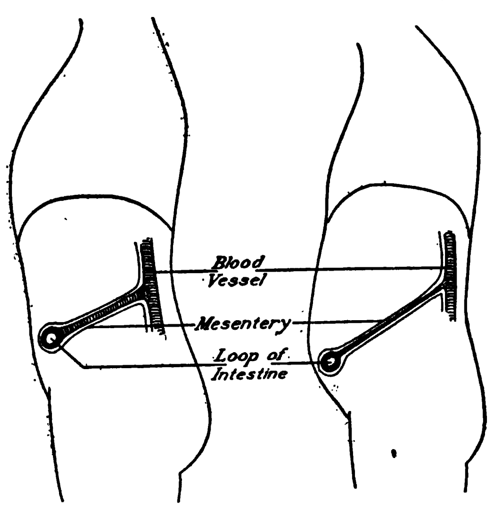


FIG. 115. — Showing how improper posture favors viceroptosis; the mesentery is stretched and the circulation to the loop of intestine is lessened.

The mesentery, which surrounds the intestines, is attached to the back wall of the abdominal cavity. It assists in holding them up in place. This support is dependent upon and is assisted by the abdominal muscles in front. People who stand with a relaxed, protruding abdominal wall, lack the support which they should receive from the abdominal muscles. There is a consequent falling down of these organs. Such a condition is known by the name viceroptosis (dropping of the viscera). Constipation is a frequent accompanying condition, due to interference with the circulation in the intestines. It is very important,

therefore, to stand and walk with the abdominal wall held in (Figs. 115, 93) and to exercise these muscles by participating in sports, games, athletics, and dancing.

The Digestive Fluids. — The digestive fluids that enter the small intestines are the pancreatic juice from the pancreas, the intestinal juice from the small intestinal glands (Fig. 114), and the bile from the liver. The bile will be discussed later in consideration of the liver. At present we will study the other two juices that come into the small intestine.

(*a*) The pancreatic juice. — The pancreas, or sweetbread, is flat, narrow, and about six inches long. It lies behind the stomach, and tapers toward the left, ending above the left kidney. Its shape has been compared to a dog's tongue, and like the root of the tongue, it bends downward at its broader end, where its duct leaves it and joins the bile duct just before emptying into the duodenum. Its internal structure resembles the salivary gland. The amount of digestion accomplished in the small intestine exceeds that in any other division of the canal, and the pancreas is the most active and powerful of all the glands. Its secretion, the panoreatic juice, is alkaline, and contains three enzymes, one of which (amylopsin) is hardly to be distinguished from the ptyalin of the saliva, and continues the digestion of the starchy food; another (enterokinase) joins with the trypsinogen of the intestinal juice and forms trypsin. Trypsin has an action similar to pepsin, and digests protein; while the third (lipase) begins the digestion of an important class of foods, the fats, which have not heretofore come in contact with a digestive fluid that could act upon anything more than the protein envelopes of the fat cells.

Two definite changes occur in the digestion of fat. At an early stage a *physical change* occurs and the fat is broken up into minute globules. This favors the second stage, but in itself is not a digestive act, because they are only in a

state of fine division and no chemical change has occurred. Such globules, floating in a liquid, form what is called an emulsion. Milk is an emulsion of cream. It is the cream in sweet milk that gives it the white appearance, for the globules of fat reflect the light. When it is churned these minute particles touch and adhere, forming butter. The *chemical change* is a splitting of the fat molecule by the action of the enzyme, lipase, producing fatty acids and glycerin. These chemical substances are absorbed by the intestinal walls and passed into the lacteals and blood stream.

(*b*) The intestinal juice. — Besides the two large glands, the pancreas and liver, there are a great number of very small glands (Fig. 114) which furnish a digestive fluid to the intestine. The intestinal glands are scattered throughout the lining membrane, and their secretion is called the intestinal juice. This juice contains:

(1) Enterokinase, which activates* the trypsinogen from the pancreas, forming trypsin.

(2) Erepsin, which splits peptones received from the gastric digestion.

(3) Maltase, invertase, and lactase, which split disacchrides into monosacchrides as described under the paragraphs on enzymes. These enzymes are often called inverting enzymes.

Absorption from the Small Intestine. — The fats are absorbed by the lymphatic system. Many minute lymphatics called lacteals (Fig. 116) are found in the villi of the intestines, and the epithelial cells of the mucous lining take up the fat and transmit it, slightly changed, to these lacteals, which unite one to another and empty into the thoracic duct. The thoracic duct empties into the subclavian veins under the left clavicle. The fats thus pass into the blood stream.

The sugars and proteins are carried by the portal circu-

lation to the liver. In this organ the sugars are changed to glucose and stored until needed by the muscles. The protein is passed and serves to build new tissue. In two different ways, therefore, do the digested food elements reach the main circulation. This provision resembles in a way the means of travel for people on the earth. Some go by one

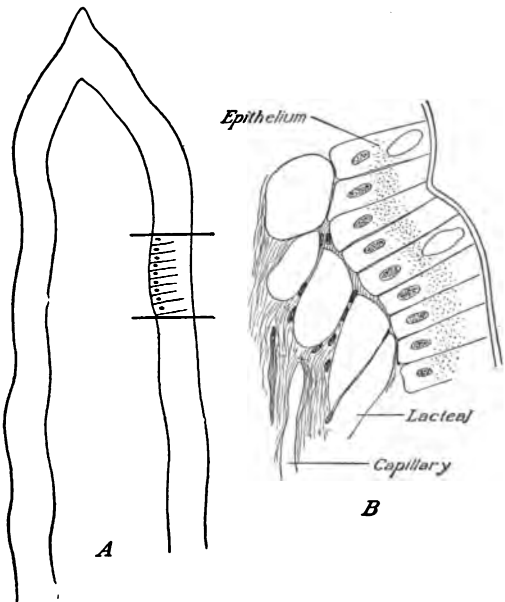


FIG. 116. — Diagram of villus, with enlarged section showing minute structure.

road and others by another. Some may go from New York to Boston by rail and others may take the boat. The result of the journey is the same — they reach Boston. The mineral matter is taken into the blood through the intestinal loops and apparently in the same way that we account for the passage of the digested protein and carbohydrates. This passage of these elements through an animal membrane at

one time was explained according to the law of osmosis,[1] but it is now believed to be accomplished by specific secretory power of the intestinal cells. In other words because the intestinal cells are intestinal cells, they are able to do this. They differ in this respect from epithelial cells in other parts of the body.

The large intestine (or colon). — The large intestine is about five feet long. Its walls are drawn into pouches, or puckers, by bands of muscles running lengthwise along it. The small intestine joins it in the lower part of the abdomen on the right side (Fig. 117). The junction is not at the end of the large intestine but above the end. The part below the junction is called the cæcum. Attached to the cæcum is a small tube called the vermiform appendix. Above the juncture the large intestine is called the colon. The ascending colon runs up along the right side nearly to the waist. It is then called the transverse colon, and it comes forward and crosses just

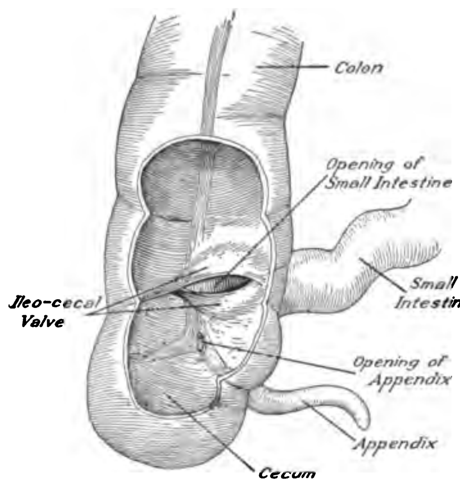


FIG. 117. — The valve between the small and large intestine; opening of small intestine and appendix. Why is the valve called ileocæcal?

[1] *Osmosis.* — "Whenever two solutions of different concentrations are separated by a membrane which is permeable to water, there will be a flow of water through the membrane in the direction of the greater concentration." This means that the solution that has the greatest concentration of substances in it will exert a greater force on the weaker solution.

in front of the lower line of the stomach. It then retreats to the rear wall and passes downward, being now called the descending colon. Near the left hip it makes a double bend called the sigmoid flexure (from sigma, the Greek letter S). The nine inches remaining are without the pouched appearance, the walls being smooth; this part is without bends and is therefore called the rectum (from Latin *rectus*, straight).

Absorption in the large intestine is very active and its contents soon lose their fluidity. Although it is mostly the watery portion that is absorbed, any digested food that may have escaped absorption in the small intestine is absorbed by the colon. How saving and economical the body is! All the undigested and indigestible food gathers in the sigmoid flexure, and descends at intervals into the rectum, from which it should be evacuated at regular intervals.

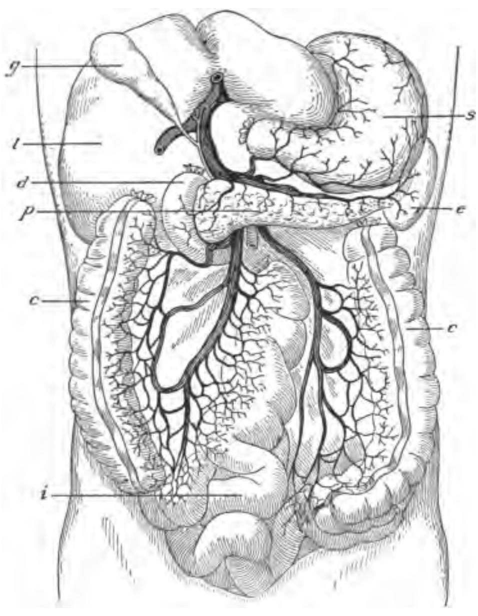


FIG. 118. — Abdominal viscera displayed so as to show the portal vein carrying the blood from the viscera to the liver. *l*, liver; *g*, gall bladder; *s*, stomach, and *d*, duodenum — these have been divided from each other; *p*, pancreas; *e*, spleen; *c*, large intestine; *i*, small intestine. The transverse colon and part of the small intestine have been removed.

Appendicitis. — The vermiform appendix (*worm-like appendage*)

is a part of the intestine which has degenerated in man because of non-use. At one time it served a purpose; today it serves none. Constipation, causing a clogging and congestion of the appendix favors infection, and this organ may become inflamed, causing appendicitis. Appendicitis may prove fatal if the operation of removing the diseased appendix is delayed too long.

Constipation. — As the undigested part of the food passes through the colon, it gradually loses its water and becomes semi-solid. This is waste material and should be removed daily by a regular habit of emptying the bowel. If the bowel is allowed to remain filled with its waste contents, there occurs absorption of poisons from this mass of waste material. These poisons taken into the blood (Fig. 118) and carried throughout the body, cause headache, lassitude, weakness, and other disorders.

The Use of Foods in Constipation. — There are many causes of constipation but it is generally recognized that improper selection of food may play an important part in the production of the disturbance. For this reason it is of value to know the foods that are laxative* from those that are constipating and to use this knowledge with reference to the selection of proper foods. All do not need a choice of laxative food and no rule can be made for all people. Food must be selected with reference to the individual's need.

Laxative	Constipating
1. Whole wheat and graham flour products, such as bread, crackers, gems, biscuits, mush	1. White flour bread, hot Pastry made with lard and baking powder preparations Cake and custard puddings
2. Fruits such as prunes, dried, stewed peaches, dried, stewed fresh fruits of all kinds	2. Meats Salted, dried and smoked meats Poultry Salted and dried fish

Laxative	Constipating
3. Vegetables	3. Vegetables
Beets	Beans, dried
Celery	
Corn	
Cauliflower	4. Cereals
Onions	Rice
Peas, green	Farina
Rhubarb	
Spinach	
Squash	5. Miscellaneous
	Cheese
4. Meats	Cocoa and chocolate
Wild game, as rabbit, duck, pigeon, quail, deer, etc.	Milk, boiled
	Tea
	Coffee substitutes made of wheat, corn and barley
Liver	
5. Oysters	

The liver. — The liver is a large, heavy organ situated on the right side of the body in the abdominal cavity and lying up under the diaphragm.

With each inspiration the liver is pushed downward and compressed by the diaphragm, the blood being forced out toward the heart, and it fills again as soon as the breathing muscles relax. This rhythmic compression is of great importance in keeping the blood supply to the liver fresh and pure, and preventing congestion in it. By tight clothing the liver is often forced downward, out from the cover of the ribs, and becomes permanently displaced. As a result, other organs, lower in the abdomen and pelvis, are crowded upon each other and also become displaced. The circulation in the liver is diminished, and hence its activity is decreased and the complexion loses its freshness.

Pain in the right side after a rapid walk is due to congestion of the liver with blood from the legs. What would pain in the left side be due to?

Anatomy of the liver. — The liver is the largest gland in the body. It is of a reddish brown color and weighs about three and one half pounds. The upper and front surfaces of the liver are very smooth and even. The under surface is very irregular; it is here that the various vessels with which this active organ is supplied make their entrance or exit. Its connecting vessels, beside the lymphatics, are the hepatic artery from the aorta, bringing pure blood; the portal vein, bringing the digested food; the hepatic vein, carrying impure blood to the vena cava; and the bile duct, carrying the bile to the intestine. The bile duct, on its way from the liver, gives off a side branch to the gall bladder. This is a little dark green bag, in which the bile is stored until it is required for digestion.

Circulation through the Liver, or Portal Circulation. — The portal vein and its function have been mentioned (Fig. 118). When it enters the liver, it does a very unusual thing; in fact, it conducts itself as no other vein in the body does, except some of the veins in the kidneys. It subdivides into capillaries. Thus the portal vein (Latin, *porta*, a gate, since it enters under a kind of archway) both begins and ends in capillaries, for it begins in the capillaries of the digestive tract and ends in the capillaries of the liver. After these capillaries have passed in among the cells, they unite again to form the hepatic veins, which go directly to the ascending vena cava. There is another large blood vessel in the portal circulation. This is the hepatic artery, which enters the liver directly from the aorta and supplies the liver cells with arterial blood with which to repair themselves and carry on their work. The capillaries from this artery unite with those of the portal vein in forming the hepatic vein. A cow's liver, cut in two, shows in places small gaping holes, which are branches of the hepatic vein.

Microscopic Structure. — If you examine the surface of a piece of liver obtained from the butcher, you will find it

to be of a dark red color, and mottled over with little areas, each measuring about one twentieth of an inch across. These are the round lobules of the liver arranged around a branch of the hepatic vein (Fig. 119). The capillaries of the portal vein and hepatic artery and the branches of the bile duct pass between these cells. Study carefully Figure 120, which represents a segment of a lobule. When you understand

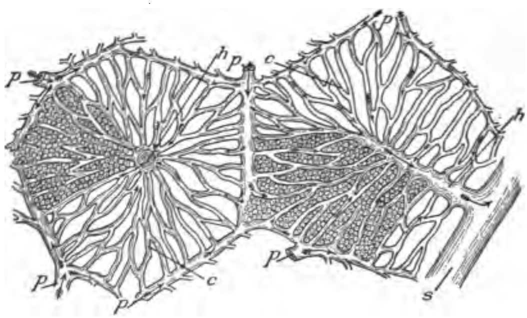


FIG. 119. — Diagrammatic representation of two hepatic lobules. The left-hand lobule is represented with the intralobular vein cut across: in the right-hand one the section takes the course of the intralobular vein. *p*, interlobular branches of the portal vein; *h*, intralobular branches of the hepatic veins; *s*, sublobular vein; *c*, capillaries of the lobules passing inwards. The arrows indicate the direction of the course of the blood. The liver cells are represented in only one part of each lobule. Trace the blood through these veins and name the vessels.

the circulation in a lobule, you will understand the circulation in the entire liver, for a lobule is the liver in miniature. Represent a lobule by a wagon wheel. The rim corresponds to the capillaries of the portal vein and hepatic artery circulating around the lobule. The spokes correspond to the two kinds of capillaries united and on the way to the hepatic vein in the hub, which will take the blood away from the liver. Between the spokes are located the hard working liver cells which get oxygen and food from the capillaries in the spokes, and relieve themselves of impurities by means of the finest bile ducts and lymphatic ducts, which begin among the cells.

Functions of the liver. — These cells of the liver have three functions: (1) to secrete bile for digestion of food; (2) to store certain food elements after digestion, and (3) to excrete from the blood certain waste substances.

Secretion Duties. — The secretion of the liver is the bile. It passes from the liver cells in a common duct that leads to the intestine and gall bladder. When the duct is filled, the bile "backs up" into the gall bladder, where it is stored until food is eaten, when it enters the small intestine close to the stomach. The bile aids in the emulsification of the fats.

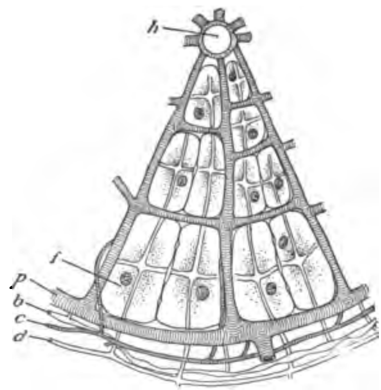


Fig. 120. — Microscope, high power. Diagram of a portion of a lobule of the liver, showing the blood vessels and bile ducts injected with fluid. *p*, interlobular branch of portal vein sending capillaries to open into *h*, intralobular branch of the hepatic vein which lies in the middle of the lobule; *b*, a lymphatic; *c*, branch of hepatic artery; *d*, branch of bile duct; into this (*d*) open the ducts which lie between the liver cells.

The bile contains an enzyme, amylase, which has the same function as the ptyalin of the saliva. It digests starch. The bile salts dissolve the fat acids, promoting emulsification and assisting in absorption of fat.

Storehouse Duties. — The sugars and protein when digested are carried to the liver. The protein passes through and goes on to the cells of the body. The sugar remains in the liver until needed.

If a frog be dug up in the first part of its winter sleep, and its liver be examined under the microscope, the cells will be found swollen and full of glycogen, a substance stored up for the winter needs of the frog. It is a carbohydrate material resembling starch and made from digested sugar,

The liver cells of a frog which has just come out in the spring will be found shrunken and containing no glycogen (Fig. 121). If a starving rabbit be killed and its liver cells examined, no glycogen will be found, but the liver cells of a rabbit which has recently been fed on turnips will be full of glycogen. If two rabbits be well fed, one kept in a cage and the other hunted around all day, much glycogen will be found in the liver of the quiet rabbit, and very little in the liver of the hunted one. The glycogen stored up is used during muscular work or starvation.

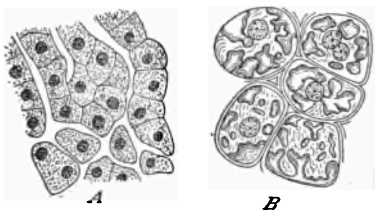


FIG. 121. — *A*, Liver cells of dog after a thirty-six hours' fast; *B*, also fourteen hours after a full meal — in the latter case swollen with glycogen.

The sugar absorbed by the small intestine reaches the liver through the portal vein. It is taken up by the liver cells and changed into granules of glycogen, to be turned into sugar again during times of hunger and hard work. Thus, only a small amount of sugar is allowed to enter the circulation at one time, only 1½ ounces in every 1000 ounces of arterial blood. If more than this quantity enters the blood, sugar passes out through the kidneys.

Excretion Duties. — The excretory function of the liver is important. As the blood containing the food passes through it, waste substances in the blood from the tissues, or poisons that may be in the food, are destroyed and the products resulting from the destruction are sent out of the body by either of two routes; by way of the bile duct and alimentary canal or by way of the blood vessels and kidneys. All the blood in the body passes through it once every three or four minutes, and as it passes it is purified. The waste products resulting from the work done in the body are made more soluble, so that they can be carried through the kidneys.

The yellow color of the bile is due to a pigment resulting from the destruction in the liver of wornout red corpuscles. The bile is partly an excretory product, but such is the economy of the system that it serves to aid digestion, and to keep the alimentary canal in an aseptic condition. A man could not smoke were it not for the liver. This organ takes up the nicotine, if not too great in amount, and destroys it. If one drinks alcohol, the liver endeavors to oxidize it and get rid of it, so that the body may not suffer harm and injury from it and usually the liver of a habitual drinker is crippled or destroyed by its long struggle with alcohol.

A man would live many years longer than he does if he were not all the time producing waste products in his body by his ordinary activities. The excretory organs are taxed to remove them. In the young child as it is growing and developing, the skin is so active, the kidneys are so healthy, and the liver is so vigorous, that the waste is all removed and the blood is pure. That is why a healthy child has so sweet a breath, such bright eyes, and so fair a skin. When he becomes older it is different. The same is true of a dog; the puppy's breath is pure, its body is clean, so that it may lie in a lady's lap or on a sofa and leave no unpleasant odor. But when he is old, the dog becomes so offensive that he has to be driven out of the house. The strong odor results from the accumulation of waste substances in the body.

Urea is the chief waste product which results from the breaking down of protein, and it is believed that the nitrogenous urea is formed by the liver. An excess of protein, such as lean meat and cheese, in the diet, produces an increased excretion of urea through the kidneys. It is obvious that excess of food and lack of exercise may lead to the disturbance of liver function. Such disturbance may be relieved by a spare diet and vigorous exercise. The poor, overworked liver should not be blamed, however, nor the statement made that "the liver is not acting." At the very

Table of Digestive Mechanism

In the MOUTH: Food and Psychic factor[1] produce Saliva which contains:
- Ptyalin acting on starch + water = dextrin + maltose
- Maltase acting on maltose + water = dextrose

In the STOMACH: Food and Psychic factor produce Gastric Juice which contains:
- Pepsin, HCl acting on protein + water = albumin, proteoses, peptones
- Rennin coagulating caseinogen and forming casein

In the INTESTINE: Acid Chyme from the stomach activates Prosecretin producing Secretin

Going in blood to liver produces BILE
1. Amylase (ptyalin)
2. Bile salts dissolve fatty acids and favor absorption

Going in blood to intestinal gland produces INTESTINAL JUICE
1. Erepsin converts proteoses and peptones to amino acids
2. Inverting sugar ensymes converting di- to mono-sacchrides
3. Enterokinase acting with trypsinogen =

Going in blood to pancreas produces PANCREATIC JUICE
1. Amylase acts like ptyalin
2. Lipase acts on fat = fatty acid and glycerol
3. Trypsinogen acts with enterokinase to form
4. Trypsin which changes protein into amino acids

[1] By psychic factor is meant the influence exerted through the brain. It is well known, and it has also been demonstrated experimentally, that the sight of food causes the flow of the saliva. When we say that food causes the mouth to water, we mean that it causes the saliva to flow, and this is accomplished by means of nerve impulses coming from the brain.

time the complaint is made, the skin and eyes may be yellow, showing the presence of too great a quantity of bile, which is a product of the activity of the liver.

Functional disturbance of the liver may result from three causes: (1) The first and most usual form is caused by fermentation and other forms of indigestion, and by the poisonous products therefrom entering the blood. (2) Stoppage of the chief bile duct because of congestion, which extends to it from the stomach. This congestion is caused by irritation of undigested food; (3) The liver cells and ducts may become choked up from excessive food.

The waste products from food elements. — When the foods are oxidized in the body there are several products of oxidation called waste products. The starches and sugars, the fats and oils, when oxidized, give rise to water and carbon dioxide. The protein gives rise to various products, of which the most important are urea, uric acid, and creatin. These are excreted by the kidneys. There are also found, in the excretion of the kidneys, small quantities of phosphate and sulphate of calcium, sodium, and potassium. Urea is a substance of great importance, as it is the most abundant nitrogenous waste substance produced by the processes of action and growth in the cells of the body. Carbon dioxide leaves the body through the lungs, and water leaves it through the lungs, kidneys, and skin.

If a man were to live all day in a small chamber placed upon very delicate platform scales, he would find that he lost weight every second of his existence except when taking food, and more rapidly at some times than at others, the amount of loss depending upon the activity of his body. The loss of weight occurs through the excretions which the man gives off. At average temperature of the air and average activity of his body, the day's loss to be replaced by food eaten, water drunk, and air breathed, would be about as follows:

From the large intestine . . .	5 oz.	excrement
From the skin	25 oz.	perspiration
From the kidneys	50 oz.	excretion
From the lungs	35 oz.	carbon dioxide and water
Total	115 oz.	

The total loss is, then, nearly 8 pounds, three fourths of which is water (nearly 6 pounds). The remainder, except the 5 ounces of excrement, consists of those waste materials (solid or gaseous) which result from the breaking down of the active living protoplasm into simple chemical substances, through the process of oxidation. This amounts to 27½ ounces and is apportioned as follows: perspiration, ½ ounce of salts, and a trace of urea; the kidney secretion, 1 ounce of salts and 1½ ounces of urea; the lungs, 25 ounces of carbon dioxide gas.

APPLIED PHYSIOLOGY

LABORATORY EXERCISES

Experiment 1. To study the intake of fluid by the body per day.

Material. — Coördinate paper, record of the number of glasses of fluid taken.

Method and observation. — Estimate the number of ounces of fluid taken by counting the number of glasses of water, milk, soda, etc., taken in one day. The common tumbler or glass will hold eight ounces. Continue this observation for one week. At the end of that time, record on coördinate paper on the abscissa the days, and on the ordinate the total ounces per day. Connect the points by straight lines. This will give a graphic representation of the fluid intake for one week.

If this experiment is performed in the warm weather, it will be interesting to carry along with this record of the fluid intake, the average temperature of the atmosphere on each day. If this is done, record the temperature on the chart and observe any relationship that exists.

Experiment 2. To test food material for starch.

Material. — Cornstarch, tincture of iodine, and test tubes.

Method and observation. —

(*a*) Mix a small amount of starch and water in a test tube to the consistency of a thin paste. Add a few drops of iodine to the mixture. What is the result?

(*b*) Add some water to a small part of a boiled potato. Mash the potato in the water. Add a few drops of iodine. What is the result? Iodine gives a deep purple in the presence of starch.

Experiment 3. To test for sugar (glucose).

Material. — Glucose, the Fehling copper and the Fehling alkaline solutions,[1] test tubes, and Bunsen flame or alcohol lamp.

Method and observation. — Dissolve some glucose in water in a test tube. To this solution add equal parts separately of the Fehling solutions and heat to boiling. The presence of glucose is determined by the change of the solution to a brick red.

Experiment 4. To test for fats and oils.

Material. — Nuts or animal fats, white paper, ether.

Method and observation. — (*a*) Rub the kernel of a nut with the covering removed on a piece of paper. Hold the paper to the light. The fat changes the light qualities of the paper. (*b*) Mash the kernel of a nut in a dish and add ten cubic centimeters of ether. Break up the kernel thoroughly and allow the preparation to stand several minutes. Filter and save the filtrate, allowing it to evaporate.

Ether extracts oil from substances and on evaporation leaves the oil.

Experiment 5. To test for protein.

Material. — White of egg (raw), nitric acid, ammonia, caustic soda or potash, dilute copper sulphate, test tubes.

Method and observation — (*a*) The Xanthoproteic reaction. Place the white of the egg in a test tube and add nitric acid. Heat gently to boiling. Cool and add ammonia. If protein is present, a deep yellow color will appear on the addition of the ammonia. (*b*) The Biuret reaction. Place the white of an egg in a test tube and add two centimeters of the caustic soda. Then add a few drops of the dilute copper sulphate solution, being careful to avoid excess. If protein is present, a purple color will appear. A blue color without any red is a negative test.

[1] The Fehling copper solution is made by adding 35 grams of copper sulphate ($CuSO_4$) to 500 c.c. of water; the alkaline solution by adding 160 grams of sodium hydroxide ($Na(OH)_2$) and 173 grams of Rochelle salt to 500 c.c. of water.

GLOSSARY

Absorption. — The process by which nourishing material is taken up by the body through the mucous membrane of the alimentary tract.

Activates. — To make active and to induce therein activity.

Alimentary canal. — The digestive tract or canal along which passes the aliment from which the body absorbs nourishing material.

Chyme. — The partly digested food as it passes from the stomach into the small intestine to be converted into chyle. From the Greek word, *chymos*, meaning juice.

Epiglottis. — A small leaflike structure above the glottis. The glottis is the name given to the upper end of the larynx.

Hydrochloric acid. — A colorless, corrosive compound (HCl). It occurs in the gastric juice in .3 to .5 per cent.

Laxative. — A substance which stimulates the action of the intestines. It acts by increasing peristaltic action.

Neutralize. — To render inert, incapable of further action. Acids neutralize alkalis, and vice versa.

Peristalsis. — The wavelike contraction that passes over the intestines and stomach due to the contraction of the circular and longitudinal muscle fibers.

Pharynx. — The back part of the mouth. The cavity from which goes the air through the larynx, trachea, and bronchi to the lungs, and food and drink through the esophagus to the stomach.

Pylorus. — The gateway between the stomach and small intestine.

Rheumatism. — A condition in the body caused by disease-producing organisms. These get into the blood and attack the membranes of the joints and heart valves. The entry is most often made through the cavities of teeth or infected tonsils. The disease is not caused by uric acid.

Tonsil. — A small lymphatic gland on each side of the mouth at the entrance to the pharynx.

Uvula. — The tiplike structure hanging down from the margin of the soft palate at the margin of the pharynx.

Villus. — A small finger-like projection from the mucous membrane of the small intestine. The plural form is villi.

CHAPTER XI

THE HYGIENE OF DIGESTION

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Digestion and health. — A wit once said that if he had been consulted at the creation of the world, he would have

made good health "catching" instead of disease. Observations show that happiness, industry, health, faith, and other of the strong elements that make up life are more contagious than misery, idleness, sickness, worry, and the other weak elements that tend to destroy life. Fear causes a tightening of the muscles and a waste of energy, as well as oppressed breathing and a lack of oxygen. Courage brings calm, full breathing which purifies the blood, and a steady and economical use of the muscles which saves the vital energy. A brave and cheerful visitor can inspire an ailing friend and assist in his recovery. A happy, unselfish teacher or pupil can dispel worry or gloom, and impart strength and increased power for work to the whole school. The body tends to health and not to disease. The dyspeptics * that we see have been able to break down their health only after long-continued attacks upon it, and outrages many times repeated. Fresh air brings health, and forces its way into the home to bring it, but the dyspeptic made every attempt to keep it out. Sunshine brings health, but he shut himself up in a stuffy ill-lighted office, a slave to dollars or to fame. He curtained the sunshine out from the home to protect the carpets and hangings from fading. Exercise brings health, but the promptings to stir about, to walk, to run, or to work with the hands, were repressed until the impulses ceased. When activity was lessened, the appetite for food diminished, but instead of following the prompting of nature, he sprinkled more salt and pepper and other condiments upon the food, that he might eat with an unnatural appetite.

By keeping up these artificial ways for months and years, he at last succeeded in breaking down his health. It took more perseverance to weaken the body than it will take to make it strong again. There must be a return to sensible ways of living with a reasonable trust in the inherent tendency of the cells to restore soundness when given a chance. If, however, he commits the folly of thinking that months

are not needed for recovery, but that disease brought on by months or years of wrong living can be cured in a few days by taking magical drugs and patent medicines, he will injure himself still more and probably lose his chance of recovering sound health.

Digestion and environment. — It is known that the race originally did not dwell in houses, and had few tools or cooking utensils. Man probably first lived in the tropics and subsisted upon the fruits which ripened in the never-ending summer, and, as he migrated to the colder climates, subsisted upon the results of the chase. That individual who refused to peel his apples because, as he said, Adam had no pocket knife, and slept with his windows open because Adam had no house, had a right principle in view. If his teeth were as sound as the teeth of primitive man, and his habit of mastication as thorough, fruit skins would be an aid to digestion.

Man possesses a stomach intended to digest the pure food of the forest, obtained by activity in the open air. If a man eats plain food and leads an active life, his appetite is a perfect guide. If he does not, it is unsafe to trust to the appetite alone, for the reason that he lives under conditions unlike those for which this instinct was built up. A cow's appetite is a certain guide to her among poisonous plants and berries, yet she will eat a bucket of paint and harm herself; the bucket of paint is beyond the range of her inherited habits. Even if man's instincts had their early strength, they could hardly guide him among the many food concoctions and preparations undreamed of by primitive man. We can train our taste into wrong ways, and we can likewise train it into right ways and into liking food that we know is wholesome.

It is found that returning to natural habits by going on camping, hunting, and fishing trips is one of the most effective hygienic measures for the restoration of health.

Hobbies about nutrition. — The subject of food and digestion is a more complicated one than that of exercise or breathing, and common sense is required to master it. Therefore, more persons fail to master it, and allow their minds to come to rest on some one fact or view of the subject and so become extremists.

Hot water. — Some would cure every digestive ill by means of water. Their belief is "water internally, externally, and eternally." They sometimes drink it as hot as it can be borne, yet hot water is very relaxing to the walls of the stomach and weakens the flow of the gastric juice. This extreme belief arose from the fact that hot water removes the mucus from a stomach suffering from catarrh (or congestion*) and diminishes the activity of the gastric glands if too much acid is being secreted.

Raw food. — Some persons have a fad called the raw food doctrine, and eat no cooked foods. They should consider that man's digestive organs are not as vigorous now as they were ages ago, before he learned the use of fire. This fad is a reaction from bad cooking. Cooked vegetables are more likely to ferment in a weak stomach than raw vegetables. The thorough chewing required by raw food is an advantage to digestion.

No condiments. — Some persons will not have condiments or any kind of seasoning, not even salt, in their foods. This is because many cooks destroy the natural flavors of the food by bad cookery and hide the result by high seasoning. There are many delicate and delicious flavors of grains, fruits, and fresh vegetables that a natural appetite takes pleasure in; but because of long use of badly cooked and highly seasoned foods the sense of taste in many persons has become so depraved and dull that they have only five kinds of taste left: the taste for grease, salt, pepper, vinegar, and sugar. Their dull nerves require everything to be very salty or peppery or sweet or greasy or sour.

Vegetarianism. — Some people have an aversion to eating animal food but will eat vegetable food only. In development, animal and plant came from the same source and life in each differs only in degree. It is known that animal protein is absolutely necessary for health. Pellagra, a very serious disease producing marked changes in the nervous system, results from the exclusion of certain essential animal food elements. Most " vegetarians " are not vegetarians at all. They are only " no meat eaters," because they eat eggs, butter, and milk and these are all animal food.

Those with whom meat does not agree, or who for humane scruples, or other causes, adopt a vegetarian diet, sometimes fall into serious error. If fruits and nuts are not freely used, but the diet is confined to grains and green vegetables, a large excess of starch is consumed, and the diet is very bulky in spite of the fact that it is greatly lacking in fat and protein. Persons who do not eat meat should replace the protein of meat with that of nuts, cheese, beans, and peas, and employ fat in the form of nuts, cream, milk, eggs, and butter.

No breakfast. — Those who eat no breakfast, make up in amount at the other two meals. Instead of taking three meals to eat the food necessary for them, they eat it in two. It is more hygienic to eat three small meals than two large ones. Moreover, one can do better work in the morning after a good breakfast. A good breakfast might include prunes, milk, rolls, and a boiled egg. The practice of eating some mushy cereal loaded with fruit and covered with cream and sugar is not to be recommended. Cooked cereal, such as oatmeal, eaten with a little butter on it is a desirable form of breakfast food.

Man's original food resources and how they have been enlarged. — Cuvier, Owen, Huxley, and other comparative anatomists agree that man was originally frugivorous; he ate tree fruit, both nuts and fleshy fruits. Tree fruits contain all the four chemical classes of foods, — proteins, fats,

carbohydrates, and minerals. The present sources of his food, besides the original nuts and fruits, are flesh, grains, herbs, and he has added them to his dietary probably in the order named above. In the warm regions of the earth, the banana, plantain, mango, orange, and cocoanut trees bear their luscious fruit the year round. But the multiplication of the race and perhaps times of drought and famine led man to use the food stored up in the flesh of other animals which had obtained it from grass and herbs. This necessity doubly increased with migration to colder climates. In the frigid zones the inhabitants live very largely on animal food. They consume immense quantities of blubber, or the fat of certain animals, such as the whale, the walrus, and the seal. This kind of diet, by sustaining the necessary bodily heat, enables these people to withstand the intense cold to which they are subjected.

Grains in their natural state are too small and collecting them was too tedious before the time of that long-forgotten genius who first thought of cultivating them in order to improve them. Fruits and grains belong to the seed part of the plant. The coarser woody leaves and stem and roots were probably not added to man's food until the art of cooking was much advanced. The degree of digestibility seems to coincide in most persons with the order of adoption of the classes of foods by the race. If one leads a sedentary life, or his digestion becomes impaired, the weedy, fibrous vegetables should be the first to be discarded from the diet, while flesh and fruits seem to furnish the main substance for invalids even after grains and starches prove hard to digest.

Present-day sources of food. — We have learned that man's digestive tract has developed with reference to plain food gathered by his own physical efforts. Man's food to-day both in its form and its method of production has undergone remarkable changes. Many articles are brought from lands far away and land transportation makes it very easy

to eat in Maine what has been grown in California. The city man may buy all his food in a shop and never in all his life produce actually one article of food. Of course, he produces in other ways. It is necessary that he make up in other ways for the lack of physical exercise that is one of the advantages gained from tilling the ground.

Nuts. — Nuts are the most concentrated and nutritious of all foods. Beefsteak is three fourths water, while nuts are less than one fourth water. Nuts are how many times as nutritious as beefsteak? This refers to the nut "meats" or kernels. Nuts may be said to consist of one half fat, one fourth protein, and the remaining one fourth, water and mineral. The fat, unlike that of butter, oil, and fat meat, is emulsified* in nuts, and does not need to be divided up before absorption by the lacteals in the small intestine. Their density encourages the habit of thorough chewing. Nuts are made up of little cells, each of which has its proportion of proteins, fat, and dextrin,* a kind of sugar. The small boy climbs the tree and gathers the nuts, cracks and eats them, and digests them thoroughly. The man stays in his office, has some one else to gather them, masticates less thoroughly, and he may find them less digestible, especially if he always eats a full meal before taking the nuts. Green or rancid nuts are not digestible. Nuts should be eaten during the meal the same as meat. They are not easily digestible raw. Persons who usually eat nuts after they have already eaten too much, consider them very indigestible. They are not digestible if eaten between meals, or if not thoroughly chewed.

Pods or legumes. — Pods or legumes resemble nuts very closely in chemical composition, but they require long and thorough cooking. Their seed coats, or hulls, consist of cellulose* or woody fiber, which may well be removed. The hulls can be loosened by soaking them in cold water before they are cooked. Beans and peas have been called the lean

meat of the vegetable kingdom, and they contain a high percentage of protein.

Fruits. — Fruits have four important advantages: (1) Their agreeable flavors are a natural and healthy stimulus to the digestion. (2) They contain vegetable acids (either citric, malic, or tartaric) that are perfect germicides,* and are of value in purifying the alimentary canal. (Fruits have almost no protein.) (3) They contain very valuable mineral salts that are of highest use to the blood and tissues. (4) The carbohydrate in ripe fruits is all in the form of levulose or fruit sugar, which is absorbed without digestion. With these advantages there is the disadvantage that fruits are largely water, so that the nutriment they contain is very scant, except in the case of grapes, bananas, and olives.

The proverb that fruit is golden at breakfast, silver at noon, and lead at night, is not true. Fruit is golden at all times, if it is sound and ripe, and if the stomach is not already filled with food. Fruit juices are valuable as restoratives to health, since they tax the digestive organs very little and are quickly assimilated. Since germs will not grow in fruit juices, a fruit diet for several meals will disinfect the alimentary canal and ward off a "bilious" attack. Juicy apples, pears, lemonade, orangeade, pomegranateade, ripe peaches, etc., are pleasanter than medicines.

Meat. — Protein is the principal food substance in meat. Beef contains the largest amount among the common meats, and pork the least. The fat of meat is also of great importance: fat is abundant in pork. Meat that is salted and smoked, or dried, or prepared in any way so that germs will not grow in it, can be kept for a long time, but its digestibility is greatly impaired. This is because its fibers have been hardened so that the gastric juice cannot readily penetrate them. Meat which has much connective tissue is tough; the most tender and digestible of meats consist almost wholly of muscular tissue and fat.

Experiments show that ordinarily one fifth of the protein in vegetable food passes through the intestine undigested and unabsorbed, and is thus wasted, while only one thirtieth of the protein in meat escapes digestion. A pound of fat requires three times as much oxygen in its oxidation as a pound of sugar, and therefore yields three times the heat and energy. The digestibility of fat is increased by the fact that it ferments with difficulty, while sugar and starch ferment more easily. Meat should be thoroughly cooked to avoid the danger of diseases from *Trichina spiralis* and other parasites.

Meat Extracts. — Researches concerning the nutritive value of meat extracts show that in none of them is a large quantity of food concentrated in a small bulk as the public is led to believe. A glass of milk contains far more nourishment than a cup of beef tea. The best way to get the nourishment out of a steak is to eat it. The beef extract contains but a fraction of the protein in beef, and all of the nitrogenous waste material allied to urea. The most nutritious part of the beef is not soluble, but the excretory part of the meat is soluble, and this is found in the beef tea or beef extract. This extract throws work upon the kidneys and is harmful. The part of the beef that has most value is thrown away in making the extract. Many lives are no doubt annually sacrificed by starvation through the popular faith in beef tea as a concentrated and nourishing food. Beef tea and meat juice can be used as flavoring agents with other food since they stimulate the secretion of pepsin, but they should not be regarded as real food.

By drying meat it can be reduced to one fourth its weight (since it is three fourths water). Thus 100 pounds of beef can be reduced to 25 pounds and sold in a form useful to travelers. The meat will keep fresh as long as it is kept dry. Water is added to the meat when it is cooked.

Milk, cheese, and eggs. — Cow's milk is suited for calves, and was intended to be obtained by sucking and to be swal-

lowed gradually. It does not contain the right proportion of food elements for infants and, therefore, must be modified when fed to infants. The casein or protein part is coagulated in flakes by the rennin, and when a child vomits coagulated milk, it does not mean that it is suffering from indigestion, although it may sometimes mean that it is being overfed. The tendency of milk to produce constipation in some persons may be explained as follows: when adults drink sweet milk rapidly, especially toward the end of the meal, when much acid is present in the stomach, the acid coagulates the casein into large lumps of curd, which may seriously disturb the digestion, for milk was not intended to be drunk rapidly. Heat retards the production of acid in the gastric juice and increases the secretion of rennin. If taken before meals, hot and slowly, milk will agree with those who have found it to produce indigestion. Buttermilk is one of the most digestible of foods.

Cheese is a concentrated food, and is one of the cheapest although not one of the most digestible forms of protein.

Eggs are valuable food and in proportion to their value are cheaper than meat. They are very digestible when properly cooked. Eggs should not be fried nor boiled hard.

Grains. — Nearly all the starch of our food is supplied by grains. They also contain from 8 to 15 per cent of a protein called gluten. The chief grains are wheat, oats, barley, corn, rice, buckwheat. The more of gluten there is in grain, the more gluey or sticky its flour will be. Sticky flour will retain the bubbles of gas formed from baking-powders or by the growth of the yeast plant. Wheat has much gluten, and its flour makes very light bread. Corn meal has not enough gluten to make it very sticky, and corn bread will not rise well. Corn contains more fat than any other grain, yellow corn containing more fat than white corn. Wheat is richer in starch and protein than any other grain. If cooked several hours, the starch of grains is so thoroughly

dextrinized that it is changed to sugar almost instantly when brought in contact with the saliva. Grains may be cooked during the preceding meal and the cooking finished in preparing the meal at which they are to be eaten. If oatmeal and other mushes are sticky, it shows the presence of half-cooked starch. Rice and oatmeal may be first browned in the oven and afterward steamed. Toast and brown crust are almost as digestible as ripe fruit and may be eaten by invalids.

Three Kinds of Flour. — There are three ways of grinding wheat to make flour: (1) Using the whole grain and the husk which incloses the grain. This makes graham flour. (2) By using the whole of the grain. This makes whole wheat flour. (3) By rejecting the outer and darker portion of the grain, thus losing part of the gluten and retaining all of the starch. This makes the ordinary flour.

Graham flour is most stimulating to peristalsis in the canal. Its large amount of waste matter furnishes something for the intestine to contract upon, and thus sweep all waste matter on and out of the body, contributing to the cleanliness of the canal. It sometimes causes congestion in irritable stomachs. Sometimes flour which is merely dark with dirt is sold for graham flour. The whole wheat flour is stimulating to the canal but is not irritating.

White flour is used more extensively because it makes white bread. This is judging the food by its appearance and not by its food value. It is believed by some that the whole wheat flour is more desirable as it contains salts, food elements, and waste material that are very important. Nations in time of war, when economy is necessary, use the whole of the wheat in the milling of flour. Nations in time of peace and plenty use white flour. Nations at peace should not be wasteful, and, moreover, they should use at all times foods which will make the healthiest and most efficient citizens.

In the Great War, Germany, on account of the shortage

of wheat, was compelled to use other cereals and even potatoes in the making of flour. As early as December 1, 1914, the Bundesrat issued a decree that no bread should be baked of pure wheat flour. The war flour prescribed "must contain at least ten parts, by weight, of rye flour to ninety parts of wheat flour. Rye flour must contain at least five parts potato flour to ninety-five parts of rye flour. The baker may increase the portion of potato flour, but bread with more than five parts potato flour must be marked with the letter "K" (*Kartoffel*, potato). If there are more than twenty parts potato flour, the figure must be added to the "K." The term bread includes loaves, rolls, etc."

Vegetables. — Root vegetables and tubers, such as potatoes, sweet potatoes, and turnips, contain a small percentage of starch. But vegetables in general consist almost entirely of water and woody fiber (cellulose). This is especially true of green vegetables, or those which consist of the leafy part of the plant. But green vegetables contain an iron-bearing albumin, which is of great value to the blood and tissues. This form of albumin is easily destroyed in the intestine before it reaches the blood, if fermentation takes place. As some leafy vegetables are more likely to ferment if cooked, there is an advantage in eating them raw. Iron and valuable mineral salts are thus obtained.

Cellulose. — Cellulose has the same chemical composition as starch. It forms the cell walls and woody fibers of plants, and is hardly digested at all by man; hence, starch requires cooking to burst the cellulose envelopes of the starch grains. Cellulose and water are the chief constituents of grass, and of greens, cabbage, and other fibrous vegetables. It forms the fibers in watermelons, which also contain cane sugar, the sweetest of the sugars. The woody skins of beans and peas are cellulose. Hence, many find the legumes more digestible in a purée, or cooked with the skins removed. Cellulose is the natural stimulant to peristalsis and activity of the canal.

Cattle digest cellulose, and with them it takes the place of starch.

Patent medicines. — There are a considerable number of people who violate laws of health and then seek to escape from the results by taking a pill or a tonic*. The digestion of food is not a mysterious act and it will proceed in a satisfactory manner, if simple rules of living are adhered to. Errors in diet can be atoned for, not by the taking of patent medicines, but by learning the art of living, and of this lesson, spare diet, hard work, exercise, and recreation form the first and last page.

Health of the body comes by living in a hygienic manner. Health will come and will stay only when the body is cared for properly and given sufficient exercise and recreation.

Shall we drink water at meals. — Food should be chewed until it is broken into fine parts and thoroughly mixed with the saliva. Thorough mastication is essential. It not only prepares the food better for digestion in the stomach but it also prevents overeating.

Drink should not be used to wash the food down the esophagus. The food should be chewed and mixed with the saliva until it can be swallowed easily. If one desires to drink water at meals and follows the right method there is no harm in so doing, but the habit of using liquid to wash the food down is easily acquired and one should be careful not to form it.

General rules modified by individual needs. — The student readily sees that the question of individual needs is important. There is truth in the old adage, "What is one man's meat is another man's poison." No cast-iron rules can be laid down for any one's life. Common sense can never be dispensed with. Persons with moderate powers of observation find by experience what is best, and they should have will power enough to adhere to what they find is best for them, although opposite ideas may be presented

to them as the only correct way, by persons of narrow views. What is enough for one is a surplus for another. Sex, age, occupation, and heredity, each has its influence on diet. The wear and tear of an active body requires a class of food which to one of sedentary occupation would be a burden. Exercise lights the fire that burns up the refuse of the body, and thus it increases the appetite and strengthens the digestion.

Indigestion. — If a person confines himself closely with brain work and takes no exercise whatever, he may not digest his food well, but he need not think his digestive organs unsound, and begin dieting himself. He should take more exercise, and by better habits of life stir up his circulation, use the food stored in the cells, and they will become hungry for more, and digestion will be perfect. There is a saying, " You can lead a horse to water, but you can't make him drink." So you may put food in the alimentary canal, but you cannot make the cells assimilate it, although, by high seasoning, you may have aroused an appetite for it. The fact that such food is not digested does not mean that the digestion is weak, it means only that too much food and too many condiments have been used.

Two ways out of a difficulty. — Exercise is the best way out of digestive troubles; yet, if a student or office man is under the delusion that he " just simply has not time " to take plenty of exercise, he may partly meet the difficulty and keep his brain clear by an abstemious diet.

Cooking. — The cooking of food should involve more than applying heat sufficient to burst the envelope of cellulose or coagulate the protein. It should convert it into a digestible condition. This is essential, but it is also important to cook it in such a way that when served it will be pleasing because the digestion of the food is dependent, as you remember, upon psychic stimuli. In this connection, it should be stated that *the frying pan is an undesirable utensil for any*

household. Roasting, baking, stewing, boiling, broiling, are good methods, but frying should be abolished.

Meat. — Meat should be roasted by putting it into a hot oven at first, to form a crust to keep in the juices, then lowering the temperature of the oven to prevent drying out and hardening. When broiling meat, it should be turned over every ten seconds to send the juices back and prevent their escape, thus broiling the meat in the heat of its own juices. Meat should not be salted until after it has been cooked, for salt draws the juices out.

Cereals. — You learned that the starch of fruit, when it ripened, was turned to sugar. Ordinary cooking bursts the cells of starch in the grain and begins the transformation into dextrin, a substance intermediate between starch and sugar. This is a great help, for the saliva does not act upon raw starch, and the pancreatic juice acts only slightly and after several hours' delay. Cooking that amounts to little more than moistening and heating the starch, is a disadvantage, and makes it more likely to ferment than if eaten raw; but thorough cooking adds greatly to the digestibility of starch. Oatmeal, cracked wheat, and other grain foods should be cooked at least 40 minutes. Rice should be washed in cold water in a colander after cooking. After washing, the rice may be reheated by steaming. It is then very palatable.

Bread is best if made of whole-wheat flour. It should be cooked in a slow oven, so that the inside of the loaf may be well baked. The loaves should be made small and not touching, so that there may be much crust. Crust (1) cleans the teeth like a brush and makes them healthy from use; (2) it increases flow of saliva by its dryness and the longer chewing required; (3) it is more easily digested than the crumb, or white portion, as it resembles sugar. Beaten bread is the most digestible, like the hoe cake and other unleavened breads. Yeast bread comes next in digesti-

bility. Baking powders containing alum, and soda, if not thoroughly neutralized by sour buttermilk, are injurious, even to the healthy.

Yeast belongs to the class of plants called fungi, that can live in darkness, and have neither leaves nor blossom. Most plants get nourishment from the soil, air, and water, but yeast and other fungi derive their sustenance from vegetable or animal matter in process of decomposition. Yeast plants are microscopic cells of oval shape, and, like other plants, require food in liquid form. They cannot absorb dry or solid food. Their most suitable food is sugar. The flour of wheat contains starch, a small amount of which is converted into sugar by the diastase which lies next the bran. Yeast grows best at a temperature of from 70° to 80°. A slow growth at a lower temperature favors the development of other micro-organisms which make the yeast unhealthy and produce bad flavors. With a high temperature its growth is rapid and of extremely short duration.

Fermentation * may go through several stages; in the first stage, or alcoholic fermentation, the yeast decomposes the sugar, splitting it into alcohol and carbon dioxid gas. This is the stage for bread-making, the gas causing the bread to rise. In the second stage, or vinegar fermentation, alcohol is changed to acetic acid — the acid in vinegar. Hard wheat has more gluten than other wheat, and the bubbles formed in its flour will not break easily. Why does bread from such wheat rise well? Why is bread set in a warm place to rise? Why does it "fall" if left to stand too long? Under what conditions does bread made from yeast become sour? Why does bread set to rise in a cold place sometimes have a bad flavor?

Vegetables. — Irish potatoes, to become mealy instead of soggy, should be put into boiling water, and, after they are cooked, the water should be poured off, and the pot should be set on the back of the stove for the potatoes to dry.

Roasting them in the oven with their skins on also retains their flavor and makes them mealy.

Onions are better if cooked, to drive off the acrid, irritating oil. Raw cabbage, which is water and cellulose, is treated by the stomach as a foreign substance, and sent promptly to the intestine; but the stomach attempts to digest boiled cabbage, and it remains there several hours. Peanuts are nutritious and digestible if properly prepared. Boiling water should be poured over the raw peanuts so that the skins can be removed. They should simmer on the stove for hours until they can be easily pressed through a colander. This with the addition of a little salt is a palatable food. Raw and roasted peanuts are not easy to digest.

Eggs. — Eggs should be cooked by placing them in boiling water and taking the pot off the stove. They cook while the water is cooling, and the albumin is jellied but not hardened.

The fireless cooker. — Cooking meat and vegetables by placing them in a closed cabinet and providing heat in the form of heated stone is a desirable method of cooking. Meats are made more tender. Vegetables can be cooked thoroughly and yet they will retain their form. A fireless cooker makes housework easier and for this reason alone it should be part of the furnishing of a home.

Times for eating. — Different nations have various habits of eating. The number of meals varies from two to five, or even eight, meals daily. Such facts show the adaptability of the stomach to different habits. It is an organ which readily forms habits, and is greatly benefited by regularity. If a person avoids disturbing the stomach between meals and allows it needed rest, both appetite and digestion are promoted. Three meals a day seem to be needed, especially by hard workers. The Greeks ate two meals a day, and developed the most beautiful and perfect bodies in the world, as shown by the statues left by them.

Exercise in relation to eating. — Very active exercise tends to hinder the work of the stomach, but facilitates that of the intestines. For a half hour after a full meal, hard work of every kind should be avoided, but hard work an hour or two later will aid digestion. The arrangement of the meals must take into account the other habits of the individual. For example, if three meals are eaten in twenty-four hours, the last ought to be the lightest; but, as business is transacted in large cities, a business man can hardly find time for a hearty meal in the middle of the day. Hence he does right in eating a lunch at noon, and having the heartiest meal come in the evening, when the day's labor is over and there is time to relax. If he takes the principal meal in the latter part of the day, he should not eat very heartily the next morning or during business hours; to do so would surfeit the system. Late suppers should not be eaten, as they prevent sound sleep. The lower animals may lie down in the shade and sleep after eating, but it is only for a short nap. A nap of ten minutes, just long enough to bring about relaxation, is often of benefit after a meal. During sleep the heart beats less frequently and with less force; the lungs are less active; the brain nearly ceases its activities; the muscles relax and become motionless; peristalsis and secretion in the alimentary canal become slow, and the digestive organs should have rest. If a person is troubled with a too great flow of blood to the brain, some light, digestible article of food taken just before retiring may bring sleep; but it should be taken simply to regulate the circulation, and should be so digestible as to give little work to the stomach. A farmer will do a better afternoon's work if he will rest for half an hour after the noon meal.

The rule that every individual must be a law unto himself may be abused by those who consult their appetites alone without reference to their common sense. If we believe that regularity in eating is desirable, the stomach and

appetite can be trained to it, although if one is used to eating at all times and between meals, the desire to do so may remain for a time. An appetite for whisky is an acquired one, and is not an evidence of a normal and healthy demand. Emaciated and half-starved persons may suffer from want of appetite, but it may be a sign that they should increase the activity of other organs, as the muscles, not that they should follow the guidance of appetite and eat insufficient food.

A good and healthy appetite comes from the expenditure of energy and rebuilding of the tissues, and a person with such an appetite enjoys best the simple foods that will best give energy and build tissue. The best pleasures of eating are for those who have appetites of this kind, not for the epicure or glutton. This is only one example of the general truth that mere pleasure seekers do not have the best pleasures; but they enjoy life best whose living is complete, all the duties and pleasures of life being given their proper place.

APPLIED PHYSIOLOGY

Exercise I

1. How do you explain the difference in the way a dog eats meat and a horse eats grain? (Compare with question 8.)
2. Clothing and shelter for man or beast economize what kind of food?
3. Why does wheat bread rise better than corn bread?
4. Why is corn bread one of the most fattening of grain foods?
5. Why is it that you can tell best about the digestibility of bread while you are slicing it?
6. What kind of persons would not find it well to take a long walk before breakfast?
7. Why are late suppers unhealthful?
8. Why should bread remain longer in the mouth than meat?
9. In snowballing what is the appearance of the hands when they itch from cold? Why does ice-water not satisfy the thirst, but often produces a craving to drink more water?
10. Why is it more difficult to swallow a small pill than a large one?

Exercise II

11. When is hunger a safe guide?

12. Why does not fat meat taste as well in summer as in winter?

13. Name organs which receive more benefit from the blood than they give to it.

14. Name organs which give greater benefits to the blood than they receive from it.

15. Why should pork be thoroughly cooked?

16. What necessary step in preparing salt meat to be cooked lessens its nutritive value?

17. Should biscuits, having a yellow tint or dark spots due to soda, be eaten?

18. Why, during an epidemic, are those who have used alcohol as a beverage usually the first to be attacked?

19. What is the effect of alcohol upon albuminous substances?

20. Explain how it is that when people speak of an inactive liver they usually mean an overworked one.

Exercise III

21. How does the possession of a gall bladder furnish evidence that man should have meal times and not eat at all times?

22. Who attains greater success in life and true happiness, the man who makes millions of dollars but loses his health by close application to money making, and has to live on gruels and soups, and does not have sound sleep, or the man who makes a living and no more, sleeps soundly, enjoys his food, and has strong nerves? Which do you regard as a truly successful man? Which does public opinion regard as more successful?

23. Do you buy more wood (cellulose) when you buy beans or when you buy nuts?

24. Do you buy more water when you buy bread or when you buy meat?

25. Which is true, the original saying: "Stuff a cold, and you will have to starve a fever," or the modern way of stating it?

26. Why is soda sometimes good medicine to neutralize a sour stomach, and very bad for digestion if eaten in bread?

27. What advantage in digestibility may a hot biscuit have over a loaf of stale bread? Vice versa?

28. Some physiologists hold that the eating of much meat causes an irritable temper. Does your observation of others or your personal experience confirm or disprove this?

29. Why do people who live in overheated rooms often have poor appetites?

30. Why may the taking of prepared pepsin weaken the stomach?

31. Why is there often an outbreak of colds when a warm moist spell of weather succeeds several weeks of cold dry weather?

32. Explain how the stomach may be weakened by the eating of predigested foods.

APPLIED PHYSIOLOGY

LABORATORY EXERCISES

Experiment 1. To study the changes which take place in the digestion of starchy foods in the mouth.

Material. — Crackers, Fehling solutions, test tubes.

Method and observation. — (*a*) Test an unsweetened cracker with Fehling solution for sugar. Note the result. (*b*) Test some saliva with Fehling for sugar. Note the result. (*c*) Chew some of the unsweetened cracker and test some of this chewed cracker with Fehling. Note the result.

What conclusion would you draw from this one experiment as regards the digestion of starch in the mouth of the experimenter? With observation of other people what conclusion could be drawn as regards such digestion in general?

Experiment 2. To study cooking processes.

1. Try at home cooking rice and then washing it in a colander and compare the result with that obtained by washing the rice before cooking. The washing process removes the sticky gluten that has been set free by the cooking process.

2. Notice the difference in the white (albumin) of a fried egg and a boiled egg.

GLOSSARY

Cellulose. — A substance that forms the chief material of the structure of plants.

Coagulation. — The process of solidification of a liquid. This may be accomplished by means of heat or by acids. When an egg is cooked the protein of the white coagulates.

Congestion. — An abnormal and excessive accumulation of blood in the vessels of an organ or a part.

Dextrin. — A brownish-white compound with the chemical formula ($C_{12}H_{20}O_{10}$). It is derived from starches by a process of removing two molecules of water. It is one of the steps in the digestion of starches.

Dyspeptic. — One who has dyspepsia. Dyspepsia is an old term to denote difficult and painful digestion. To-day the term "indigestion" is used and is more acceptable. In one respect the older term is satisfactory. It comes from Greek origin, *dys* meaning bad, and *pepto* cook. Bad cooking is often the cause of indigestion.

Emulsify. — To convert into an emulsion.

Emulsion. — A liquid mixture in which a fat or oil is suspended in minute globules. Milk is an emulsion. The butter fat is suspended in such minute globules that they do not appear in fresh milk. After milk has "stood" for some time, the fat will rise to the top because it is lighter than the other elements in the milk.

Fermentation. — A chemical decomposition of an organic compound usually induced by living organisms. The action of enzymes in causing chemical change in digestion is also spoken of as fermentation.

Germicide. — A substance capable of killing germs (Bacteria). Could be called bacteriocide.

Tonic. — A medicine or regimen having the power to invigorate and build up the body. Medicines chiefly by improving the appetite. Fresh air, out-door exercise, change of activity, sleep are the best tonics for the body.

CHAPTER XII

THE CIRCULATION OF THE BLOOD

How the circulation of blood serves the body. — It will be recalled that the tissues composing the body are made up of cells; that these cells are active and must have food; that the food for the cells is the nutritive food elements (protein, fat, and carbohydrate) and the non-nutritive food materials (water, and salts); that some of these substances undergo slow combustion in the tissues; that this combustion or uniting with oxygen gives rise to carbon dioxide and other waste substances. The blood which serves as the vehicle for the transportation of food and the removal of

waste from the cells to the excretory organs, has other important functions.

It also serves in equalizing the temperature of the body. The heat of the body is continually kept at a certain point (98.6° F.) in health, by the blood vessels bringing to the surface of the body the heated blood and allowing radiation of this heat to occur. The blood also serves to protect the body from infections by having in its plasma, substances which protect the body. The blood also carries secretions from internal glands which control growth and development.

The nature of circulation. — To have a circulation, there must be a fluid, a pump, and a system of tubes or passages through which the fluid is forced. In a city water system, the fluid is the water, the power station provides the pump, and the mains are the tubes. In the body the fluid is the blood, the pump is the heart, and the tubes are the arteries and veins. In studying the circulation, therefore, we must study the blood, the heart, and the blood vessels.

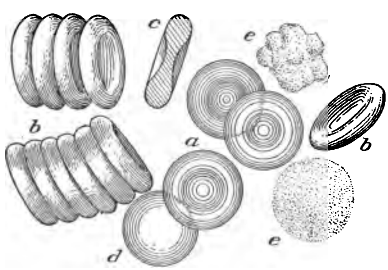


FIG. 122. — Blood cells. *a*, red corpuscles seen from the side; *b*, red corpuscles, seen on edge, are run together in rows; *c*, section through middle of red corpuscle; *d*, red corpuscle swollen with water; *e*, white corpuscles.

Composition of the blood. — When seen under the microscope blood no longer appears of a uniform red color. It is found to consist of a clear, colorless liquid called plasma,* in which floats a multitude of small bodies called corpuscles.* The corpuscles themselves are seen to be of two kinds. By far the greater number are round, yellow, and flattened, but a few, perhaps one in four hundred, are round, white, and globular, and larger than the yellow ones (Fig. 122). The yellow ones

are called the red corpuscles, because the light shining through a great number of them gives the blood a red color. The white ones are called the white corpuscles. The following presents in tabular form the elements making up the blood:

- Blood
  - Cells
    - Red blood cells
    - White blood cells
      - lymphocytes *
      - leucocytes *
  - Plasma
    - Water — 90 per cent
    - Gases
      - oxygen
      - carbon dioxide
      - nitrogen
    - Food
      - protein
        - albumin
        - globulin
        - fibrinogen
      - carbohydrate — glucose
      - fat
    - Inorganic salts
      - chlorides, carbonates, sulphates, phosphates
      - of
      - sodium, potassium, calcium, magnesium
    - Waste products — urea and uric acid
    - Protective substances — agglutinins, etc.
    - Growth determiners — hormones *

The work of the red corpuscles. — The red corpuscles serve to carry oxygen (Fig. 123). They contain a substance in their protoplasm which has the power of combining chemically with oxygen. This substance is hæmoglobin. When the red cell passes in the pulmonary vessels through the lungs,

the hæmoglobin "takes up" oxygen in accordance with the needs of the body. This is an important fact. When the body has used oxygen in large amounts, the red cells will be depleted and so will take up more when they make their next trip through the lungs.

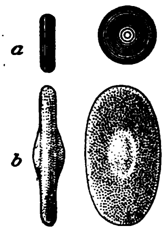


FIG. 123. — *a*, human blood corpuscles, side and front view; *b*, frog's blood corpuscles, side and front view. Both are drawn to the same scale.

The work of the white corpuscles. — The blood of healthy persons possesses a certain power of destroying germs of disease which may enter the body; this is called its germicidal or germ-killing power. The germs are minute one-celled organisms to be seen only through a powerful microscope. Some float in air; others are found in liquids or solids. Most kinds of germs are not harmful to man. For instance, there is a germ which gets into milk and causes it to turn sour. The yeast germ, used in bread making, is a microscopic one-celled plant which obtains its nourishment from sugar.

The germicidal power of the blood rests in part, at least, in the white corpuscles. When the flesh is cut, or when bacteria lodge in the tissues, these little scavengers may be seen collecting at the danger point in great numbers; some of the germs are devoured bodily by the white corpuscles; others are killed probably by substances in the plasma which were formed by these little guardians. In no way is the provision for our welfare better shown than by the existence of these corpuscles (Fig. 124).

The work of the plasma. — That the blood may flow readily through every little tube, it must be liquid, hence a large part of it is water. The water is important also as a solvent for the salts, waste products, food, and other substances carried. The gases present in the blood are nitrogen, oxygen, and carbon dioxide. The nitrogen is inert and is only ab-

sorbed physically. The oxygen is in chemical combination with the hæmoglobin of the red corpuscle. The carbon dioxide which results from combustion in the cells is removed by the blood and carried partly in chemical combination with various salts and partly in physical solution in the plasma. The food elements are all represented. The proteins are albumin, globulin, and a special protein concerned in coagulation.

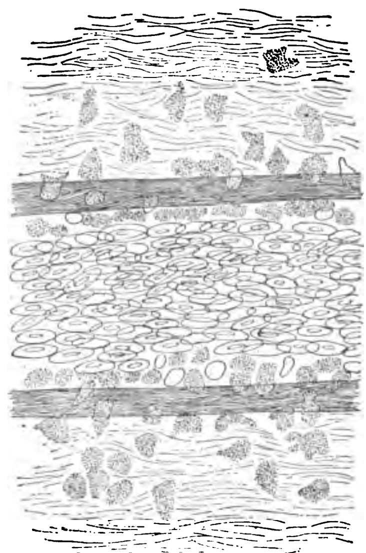


FIG. 124. — Migration of white corpuscles through the walls of a vein. They are shown in different stages of migration. The red corpuscles remain in the stream.

If some blood from an animal is allowed to stand in a vessel, it soon becomes a red, jellylike mass. This change is called coagulation. If we let the coagulated blood stand, it gradually separates into two parts, — a light yellow liquid called serum, which is colored by a few blood cells, and a semi-solid mass called the clot, which contains most of the cells together with some threadlike fibers (Fig. 125). A

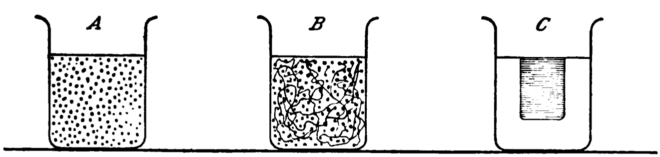


FIG. 125. — Diagram to illustrate the process of coagulation. *A*, fresh (corpuscles and plasma); *B*, coagulating (formation of fibrin); *C*, coagulated (clot and serum). Plasma minus fibrinogen equals serum. Corpuscles plus fibrin equal clot.

substance called fibrinogen was in solution in the plasma. It has solidified into fibers, called fibrin * which, by entangling the red and white corpuscles, caused the formation of the clot. The portion of the plasma that remains liquid is composed of the water with all the other elements in solution. The carbohydrate element is represented by glucose. The fats vary in amount. During digestion the fat content is higher than in the intervals between digestion. The salts of the plasma are mainly salts of sodium. There are some potassium salts in the corpuscles, but the inorganic matter is represented largely by the salts in the liquid portion of the blood.

The waste products which result from the breaking down of chemical compounds in the production of energy are present in the blood on their way to the organs of elimination, the kidneys, skin, and lungs. Urea* and uric acid,* which arise mainly from protein oxidation, carbon dioxide, which comes from the breaking down of carbohydrate, and fat are the chief substances.

The protective substances in the plasma serve to kill bacteria. It is known that many diseases produce a condition as an after effect that protects the individual ever afterwards from that disease. Some of these substances act separately and others in conjunction with the white corpuscles. According to their function, they have been given names, such as bacteriolysins (*to dissolve bacteria*), agglutinins * (*to produce a cluster*), precipitins (*to cause a precipitate*), opsonins (*to prepare as food for*). The last three are apparently concerned more with making it possible for the white corpuscles to attack the bacteria.

The growth determiners are substances produced by glands in the body. The secretions are taken up by the blood and control, in some way not clearly demonstrated, the growth and development of the body. The glands producing these secretions are thyroid, thymus, pituitary, adrenal, pancreas, ovary, and testicle.

The heart as a pump. — The organ which gives the push or impulse to the blood and causes it to circulate in the tubes or vessels is the heart (Fig. 126). The tubes that conduct the blood away from the heart to the organs and tissues are called arteries. The tubes through which it returns to the heart are called veins. The very small tubes that take the blood from the arteries to the veins where it begins its return journey are called capillaries. The blood must circulate in order that it may go to the digestive organs to get food, or to the lungs to get oxygen, and to all the tissues in

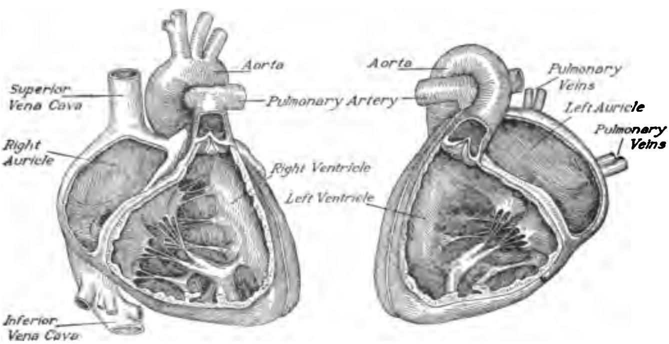


Fig. 126. — Diagrammatic section of heart.

order to distribute these things, and to carry away waste materials to the organs that will free the body of them. Can you see in your mind the dark color of a piece of beef and the lighter color where a fresh cut is made? Blood going from the lungs to the tissues is bright red, about the color of a piece of new beef when the knife cuts into it. The blood going from the tissues to the lungs is darker, about the color of the outside of the piece of raw beef some time after it is cut.

The heart is situated in the chest, between the two lungs. It is a hollow muscle, and has the remarkable power of contracting and relaxing itself with periodical regularity. The

movement of contraction is called the systole*; the relaxation is called the diastole.* The period of systole is the systolic phase; the period of diastole is the diastolic phase.

The heart is divided by a vertical partition into halves (Fig. 127). The right half receives the dark blood from the body and sends it to the lungs. The left half receives the

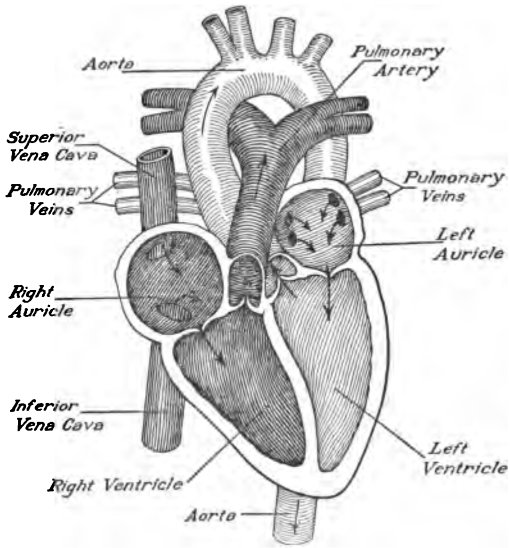


FIG. 127. — Diagram to show the course of the blood through the heart. The vessels containing impure blood are drawn darker than the others.

bright blood from the lungs and sends it to every part of the body. Each half is also divided by a horizontal partition, but unlike the vertical ones, these partitions are pierced with openings for communication. The heart, therefore, contains four chambers; the two upper ones are called auricles, the two lower ones ventricles. The right auricle communicates with the right ventricle just below it, and the left auricle communicates with the left ventricle.

How the heart works. — From all parts of the body (except the lungs) the blood arrives at the right auricle, dark red in color, and charged with carbon dioxide, a gas that is unfit for supporting life. The blood has come through two large veins, the superior vena cava, from the head, arms, etc. (Fig. 127), and the inferior vena cava, from the lower parts of the body. The first chamber of the heart that it enters is the right auricle. The auricle contracts and presses the blood into the right ventricle (Fig. 128). It begins to squeeze together just around the openings of the veins, so that it closes their openings. The blood, owing to this, cannot go back into the veins, but is forced into the ventricle. The right ventricle, thus filled with blood, at once begins to contract. The first effect of the pressure thus produced is to force blood behind the flaps of the tricuspid valve, the valve between the auricle and ventricle, consisting of three flaps made of white fibrous tissue. The blood behind the flaps brings the flaps together and so blocks the way to the auricle (Fig. 129). The contraction of the ventricle goes on, and soon the blood presses hard enough upon the semilunar valve to open it and go on into the pulmonary artery (Fig. 129); the semilunar valve opens when the pressure in the ventricle is greater than the pressure in the pulmonary artery.

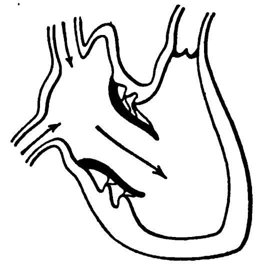


FIG. 128. — The right side of the heart. The blood flowing through the tricuspid valve into the ventricle.

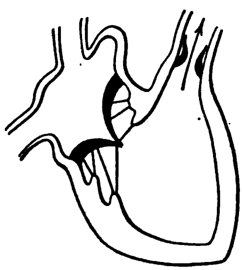


FIG. 129. — The blood going through the pulmonary artery to the lungs. Tricuspid valve closed, semilunar valves open.

When the ventricle has emptied itself, it relaxes. The

semilunar valve is composed of three pockets, which the swollen pulmonary artery fills with blood as soon as the ventricle begins to relax. The pockets of the valve are thus pressed together, and no blood flows back into the ventricle. The auricle was relaxing while the ventricle was contracting, and it is already filled with blood that has flowed in from the veins. After a short pause, it again contracts; and the same action is repeated. More and more blood is thus driven by the right ventricle through the semilunar valve into the pulmonary artery, so that the blood which is already in the artery is sent on through the numerous small branches and through the multitude of fine tubes called capillaries, which go through every part of the lungs.

In the lungs the carbon dioxide passes into the air passages, and the oxygen brought by the breath goes into the blood of the capillaries, which changes in color to bright red. The capillaries unite again to form the pulmonary veins, which lead back to the heart. We thus see how the blood is sent from the heart through the lungs and back to the heart. How is the blood sent through the body and back to the heart? We shall find that this is done by the left side of the heart; that the two ventricles, acting like pumps, work in unison; that, in fact, a wave of muscular contraction starting at the top of the heart passes downward over both sides of the heart at once, both auricles contracting at the same time and then relaxing as the contraction passes to the ventricles.

As we learned, the pressure from the right ventricle keeps the blood moving through the pulmonary artery, the capillaries of the lungs, and the pulmonary vein. It returns to the heart again, and this time it enters the left auricle. When the left auricle is full, it contracts and drives the blood through a valve called the mitral valve, into the left ventricle (Fig. 130). The left ventricle (at the same time with its mate, the right ventricle) then contracts, forcing the blood behind the flaps of the mitral valve, closing the way

back to the left auricle. The pressure of the ventricle opens the semilunar valve in the mouth of the great aorta, which is the large artery carrying the blood from the left ventricle. The aorta takes the blood to every part of the body

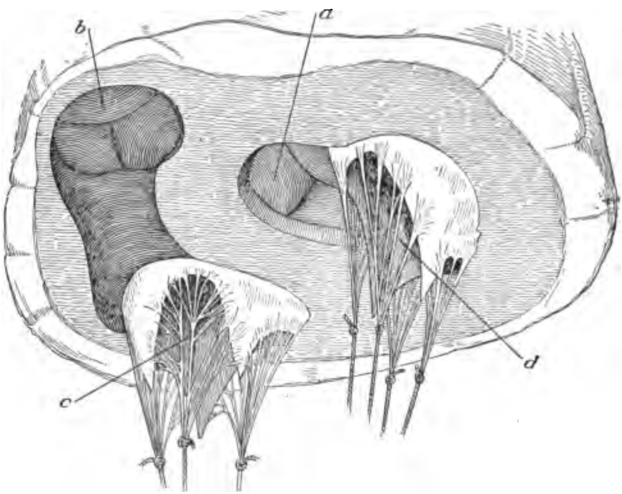


FIG. 130. — View of the orifices and valves of the heart from below, the whole of the two ventricles being cut away. *a*, aorta; *b*, pulmonary artery, each with its three cups of the closed semilunar valves seen convex from below; opening between right auricle and right ventricle, surrounded by three flaps of the tricuspid valve with chordæ tendineæ between them, to which three cords are tied, taking the place of the papillary muscles. *d*, opening between left auricle and left ventricle, with two flaps, of the mitral valves and chordæ tendinæ, to which cords are tied.

This figure may be said to show the roof of the two ventricles, with the two great valves, by which the blood enters the ventricles and the two great valves by which it leaves them. All the openings of the ventricles are upward.

except the lungs. It gives off smaller arteries, and the division is repeated until arteries are supplied to every organ and tissue. In the tissues the arteries empty into smaller tubes called capillaries. The aorta, with its branches, becomes distended with blood, and as more and more is forced into it by the left ventricle at each heart beat, the

distention is kept up, and some of the blood already in the aorta is forced along its branches, and the same pressure forces it through the capillaries and into the veins (Plates V and VIII).

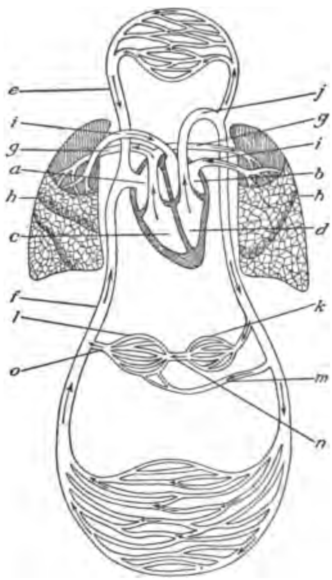


FIG. 131. — Diagram illustrating the circulation. *a*, right auricle; *b*, left auricle; *c*, right ventricle; *d*, left ventricle; *e*, vena cava superior; *f*, vena cava inferior; *g*, pulmonary arteries; *h*, lungs; *i*, pulmonary veins; *j*, aorta; *k*, alimentary canal; *l*, liver; *m*, hepatic artery; *n*, portal vein; *o*, hepatic vein; follow the arrows and see whether you come around to the starting point again.

The blood flows slowly through the capillaries and performs its function of exchanging substances needed for those used up. It next goes into the veins on the return journey to the heart, where it enters the right auricle again, which was our starting place in this description (Fig. 131).

The circulation traced. — The blood comes from the tissues through the veins and enters the right auricle, goes through the tricuspid valve into the ventricle, then through the semilunar valve it enters the pulmonary artery. Traversing the capillaries of the lungs, it goes by the pulmonary veins, to the left auricle, then through the mitral valve to the left ventricle, thence into the aorta by the semilunar valve, thence to the capillaries of the system, thence to the veins, and through them it returns to the heart, completing the circulation.

Blood vessels as tubes. — The blood tubes are built of tissues so arranged that they provide the correct kind of

tube needed for the circulation of blood in the body. They differ in their properties from galvanized pipe that is used in water supply systems, and these differences are important.

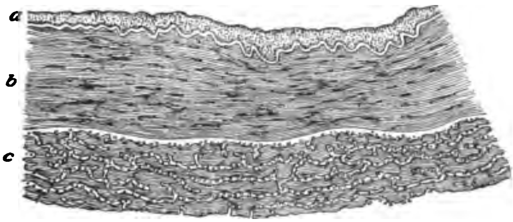


FIG. 132. — Transverse section of part of the wall of an artery, highly magnified. *a*, epithelial (endothelial) layer, or inner coat; *b*, muscular layer, or middle coat; *c*, outer coat, consisting of connective tissue.

In order to understand how the arteries, veins, and capillaries are adapted to their work, we will study their anatomy. We shall find three kinds of tissue (Fig. 132) used in their construction, — epithelial tissue to prevent friction,* connective tissue to give both strength and elasticity,* and muscular tissue to enable the vessels to change in size.

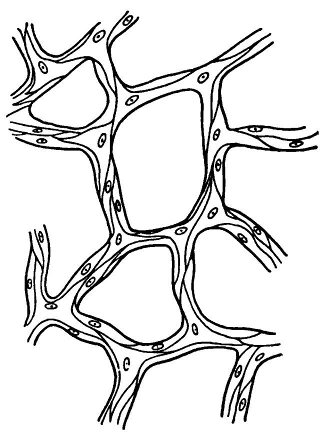


FIG. 133. — Epithelial cells forming the walls of capillaries. The nuclei and the outlines of the cells may be seen. The forming of the thin tubular walls of the capillaries is one of the most curious among the many wonderful feats accomplished by the cells.

Structure of the vessels. — The epithelial tissue forms the innermost layer of the vessels. The endocardium or inner lining of the heart is formed of this membranous layer, and is continued throughout the arteries, capillaries, and veins. In these vessels, the inner coat is called the endothelium. The epithelial cells forming this smooth layer are thin and flat, and

serve to diminish friction. The walls of the capillaries, the smallest vessels, consist simply of this epithelial membrane (Fig. 133).

The middle coat is muscular and is made up of the muscle cells arranged in circular fashion. The muscle is more abundant in the arteries than in the veins, but is present in both.

The outer coat is made of connective tissue. This layer is outside of the muscular tissue, and forms the outer surface of the artery. It contains both white fibers and yellow elastic fibers (Fig. 132). In fact, some of the yellow elastic fibers (Fig. 132) are found also in the other coats. The muscular and connective tissue layers become still thicker in the larger arteries. So the wall of an artery consists of three layers: (1) the endothelium; (2) the muscular coat; (3) the connective tissue coat on the outside (Figs. 132 and 134). The arteries are, therefore, very firm and elastic, and do not collapse when they are cut, but stand open, and the flow of blood through them is unobstructed. The walls of the veins consist of the same three layers. Their walls are not so thick as those of the arteries, for the muscular and connective tissue layers are much thinner (Fig. 134). When a vein is cut it collapses, that is, the thin walls fall together, and the bleeding is stopped unless the vein is large.

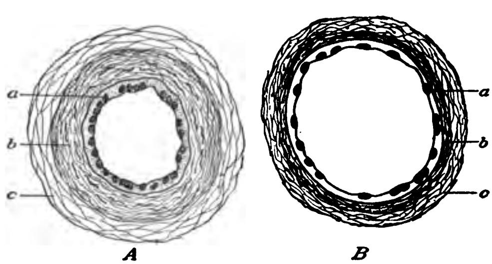


FIG. 134. — An artery and corresponding vein cut across. *A*, artery; *B*, vein; *a*, endothelial cells; *b*, muscular coat; *c*, connective tissue. Notice the nuclei of endothelial cells, and the greater amount of muscular tissue in the artery.

Arteries and veins compared. — (If this is made a written exercise, underline the words which you supply.)

Walls. — The walls of the —— are very elastic, while the walls of the —— are slightly elastic. The walls of the —— are thicker and stiffer than the walls of the ——. It is necessary that they should be so, because they must sustain the —— of the ——.

Work of Each. — The arteries take pure blood from the —— to the ——, and impure blood from the ——to the ——. The veins take pure blood from the ——to the ——, and impure blood from the —— to the ——.

Connections at Heart. — The —— are connected with the auricles. The —— are connected with the ventricles.

Rate of Flow. — The blood flows more rapidly in the ——.

Manner of Flow. — The blood in the —— flows uniformly. The blood in the —— flows ——.

Control of flow. — The —— are abundantly supplied with ——. The —— have none.

Location. — The arteries as a general rule are located ——. The veins are generally located ——. This adds to the —— of the body.

Definitions. — The arteries are tubes that carry blood (both pure and impure) —— the ——.

The veins are tubes that carry blood (both pure and impure) —— the ——.

Accidents. — If an artery is cut, the pressure is to be applied —— the cut and the ——. If a vein is cut, the pressure is to be applied —— the cut. A cut vein may be told from a cut artery in the three following ways: —

Adaptation of the vessels. — The white fibers of the connective tissue coat (Fig. 132) give strength and firmness to the vessel, and the yellow elastic fibers give elasticity. The muscular, or middle coat enables the arteries and veins to change in size, and the inner, or endothelial layer gives smoothness and prevents friction. Why are these three properties necessary to blood vessels?

Elasticity of the Blood Vessels. — The aorta and its branches are full of blood all the time. When the left ventricle with its great muscular walls contracts, the blood cannot move forward into the narrow arteries and capillaries fast enough to make room for the new supply so suddenly sent out of the ventricle. Therefore, the aorta becomes more than full. If a cup is full, it cannot become "fuller"; not so with an artery. The yellow elastic fibers of its connective tissue allow it to expand as a thin rubber hose does under pressure. The first part of the aorta having expanded to receive the incoming blood, the portion of the aorta just ahead of the expanded portion is less tense, or tight, so the stretched elastic fibers contract and force blood into it, expanding it in turn. Thus a wave of expansion travels along the blood vessel. It is called the pulse and may be most easily felt in the wrists and neck. The distended elastic walls exert pressure on the blood in the arteries, and this presses some of the extra blood out of them into the capillaries. As much blood as is being pressed on into the capillaries is being thrown into the aorta by the beat of the heart; so that during life a distention is always kept up, and the blood in the vessels is always under pressure. Although the arteries may get rid of the additional distention following each heart beat, there is a normal distention that always remains. It has existed ever since life began, and will remain until the heart ceases to beat. The pulse, therefore, is only an additional distention following the contraction of the ventricle.

You should not think that the muscular layer actively contracts and helps to send along the pulse; for the pulse is simply the passive stretching and contracting of the elastic tissue; as a wave travels across a pond when a stone is dropped into the water. The force of the pulse is furnished by the heart. What, then, is the purpose of the muscular layer in the arterial wall?

Use of the Muscular Coat. — The body of an adult contains about five quarts of blood. We have learned that the blood supplies the substances needed for the activity of each organ. If an organ is working, it needs more blood than usual, and it is supplied by the other organs that are at rest; they get along with less blood for the time. The muscular coat of the blood vessels makes this possible. This coat is usually in a condition of slight contraction, but the nerves controlling the muscular coat in the blood tubes of the active organs may cease to act, thus allowing the muscular coat to relax and the blood tubes to enlarge under the pressure from the heart, so that the active organs may obtain the additional supply of blood needed. While this is happening, part of the pressure in the blood tubes of the inactive organs is relieved and they become smaller. If cold air strikes the face, the nerves stimulate the muscular coat of the blood tubes in the face to contract more strongly than usual, and the face turns white. This driving of the warm blood from the face saves heat to the body, which would be lost if the warm blood remained in the skin. Thus the amount of blood circulating in any organ is regulated by means of the muscular coat of the blood vessels and of the action of the nerves upon this coat.

Use of the Inner Coat. — We learned that the inner coat of the heart and blood vessels is made of epithelial tissue, like that which forms the outer layer of the skin, and the smooth lining of the mouth and other organs. This lining membrane is very smooth and thus friction is lessened. The friction, however, is inconsiderable in the large vessels; but in the smaller vessels it is greater; and in the minute capillaries it becomes of very great importance. We see, therefore, why it is necessary to have this smooth coat in the capillaries, although the muscular and connective coats are not prolonged into them. It should be stated here that although the extremely minute size of the capillary tubes

increases the friction and the pressure which the heart must expend in sending the blood through them, yet their resistance to the blood flow is lessened by their great capacity. The united capacity of the capillaries is six hundred times that of the blood arteries that supply them. In the capillaries the blood flows slowly like a river which flows into and out of a lake.

Blood pressure.* — The force with which the heart sends the blood into the vessels and the resistance offered to the flow produces a pressure in the arteries. This pressure is greatest in the aorta and gradually decreases in the course of the vessels until in the veins that come into the heart it has fallen nearly to zero. This pressure in the arteries is fluctuating. At each beat of the heart it is increased by the push given by the volume of blood forced out of the left ventricle, but as this wave of pressure passes toward the capillaries it grows less just as the ripples on a lake will decrease in size from the point where a stone was thrown into the water. This wave of pressure gradually decreases, until in the capillaries the flow of blood is now constant, and owing to the resistance the pressure has become less. After passing through the capillaries, the pressure in the veins continues to fall until it reaches the heart again.

We shall learn later how the contractions of the muscles and their squeezing effect upon the veins passing through or beneath them, aid the heart to move the blood; also how the expansion and contraction of the lungs act as a great pump; and how these aids, together with changes of posture, enable the blood to reach the heart again. If one stands perfectly still for some time, the blood, owing to its weight and the lack of pressure on the veins, slowly congests in the veins in the lower part of the body, and the consequences may be serious.

Hence the pressure is greatest in the arteries, less in the capillaries, and least of all in the veins.

How the pressure is measured. — This blood pressure, as it is called, can be measured (Fig. 135) and it is found that for normal adults it is nearly constant. The systolic pressure is that pressure which exists during the contraction of the heart and is stated to be from 110 to 120 m.m. of mercury[1]; the diastolic pressure is that pressure existing during the relaxation of the heart and is found to be about 65 m.m. of mercury. It has been found also that whatever increases the force of the heart's beat will increase the blood pressure and vice versa; and whatever increases the resistance to the flow in the capillaries will increase the blood pressure and vice versa.

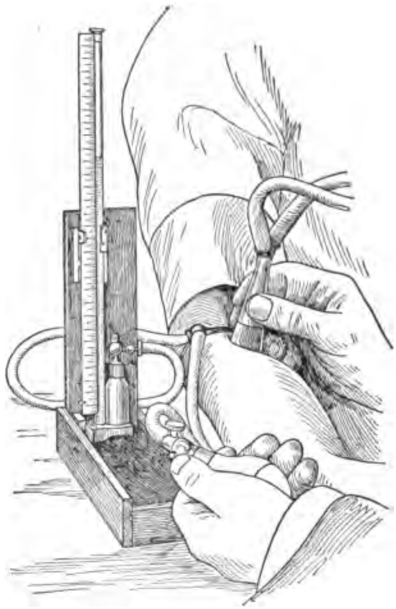


FIG. 135. — Blood pressure machine (sphygmomanometer). This instrument determines the force which exists within the arteries under different conditions.

The blood pressure is an indication of health in the body and hence it is measured to determine certain conditions. The instrument used for measuring the pressure is called a sphygmomanometer (Fig. 135).

[1] Blood pressure is usually measured in terms of millimeters of mercury. This means that the force exerted in the blood vessel would support a unit column of mercury of a certain height. The height in this case would be 110 to 120 m.m. The examination of college freshmen by Dr. Lee at Harvard, and my own examinations at the University of Cincinnati, indicate that the normal is higher than the 120 m.m. usually given. It may be considered normal at 130 m.m. mercury.

Modification of pressure and blood flow. — We learned that the ability to do this lies in the muscular or middle coat of the vessels, and that the muscular coat in turn is controlled by the nerves. The nerves that control the sizes of the blood vessels are called vasomotor nerves and are of two kinds. One kind, the constrictor nerves, stimulates the walls of the blood vessels to contract, while the other kind of vasomotor nerves, called the dilator nerves, neutralizes or inhibits the effect of the constrictors, and thus allows the blood tubes to enlarge. The regulation is involuntary, or beyond the control of the will; for instance, the blood vessels of the brain may become enlarged and the great pressure there cause a headache, but the will cannot drive it away. We sit before a fire, and the face becomes red as the warmth soothes the constrictor nerves into inactivity; or the constrictors leading to the face may become paralyzed by mental confusion and we blush.

The amount of blood passing through one organ may be increased by the vasomotor nerves, but it is only because the amount going through the enlarged vessels of that organ has been withdrawn from other organs whose blood tubes, not being enlarged just then, afford greater resistance to the passage of the blood than the dilated vessels afford. But can the total amount of blood reaching, in a given time, not a single organ only, but all the organs in the body, be increased? Yes, for if the one and one fourth gallon of blood flow faster all over the body, more fresh blood will reach each organ. This is accomplished by faster or stronger beating of the heart.

During rapid general exercise, as running, when the demands of the body are increased, the heart beats faster, as you have doubtless observed. When the body in general is at rest, as during sleep, the heart beats more slowly. Thus the general blood supply is regulated.

But how is the heart itself regulated? For these facts

show two things: first, that we cannot directly control it by the will; and second, that there is something in the body that does control the heart, and perhaps our wills may influence the beating of the heart indirectly. The heart, like the blood vessels and the muscles in general, is supplied with nerves; but there is this difference, namely, that the heart can go on beating without receiving impulses along its nerves. The heart of a frog, after being cut out of the body, will go on beating for several hours if it is kept moist; if it is cut into several pieces, the pieces will go on beating. It is the property of the heart muscle to contract, and it will do so as long as its protoplasm is alive.

Need for modification.—We have learned that there is a mechanism by which the amount of blood in any part may be modified. It is indeed necessary that this be so. The necessity for this comes from the fact that if the one and one fourth gallon of blood were evenly distributed, none of the organs would be capable of any powerful and effective action. A person weighing 157 pounds has only 12 pounds of blood, for the blood is $\frac{1}{13}$ of the total weight of the body. There is not enough blood in the body to distend all of the blood vessels at once. The skin alone with all of its blood vessels distended could contain two thirds of all the blood in the body. The veins have twice the capacity of the arteries; they could contain every drop of blood in the body.

When the brain works, it requires more blood. When digestion is in progress, the lining of the digestive organs blushes a rosy red and the digestive fluids are poured out. During the digestion of a hearty meal, one will not do his best thinking. When a muscle is used, the dilator nerves act, the blood tubes in the muscle become enlarged, and its supply of blood increases to serve it during its action.

The impulses that run along the vasomotor nerves arise in the enlargement at the top of the spinal cord called the me-

dulla oblongata. The part of the medulla that in this way regulates the caliber of the arteries is called the vasomotor center. It is constantly sending impulses along the constrictor fibers so as to keep the muscles of the arteries slightly contracted. The vasomotor center thus keeps a rein upon the arteries, holding them in a condition of tone, as this slight contraction is called. Sudden paleness, due to fear, is brought about by extra strong impulses from the vasomotor center, causing the muscular walls of the small arteries of the face to grip the vessels tight and driving the blood from the face. Alcohol destroys the tone of the blood tubes. From temporary drinking the face becomes red; from habitual drinking swollen blood tubes in the nose become purple and the "rum blossom" results.

The heart rate. — The rate of contraction of the heart is controlled by nerves. The nerves act not to make the muscle contract but to regulate the frequency of the beats.

A nerve called the vagus nerve, extending from the medulla oblongata to several organs, goes to the heart; and gentle impulses which are almost always passing down the vagus nerve from the medulla oblongata, restrain the heart from too great activity, and are the chief means of regulating the strength and frequency of its beats. When an animal requires a greater supply of blood, as in running, these impulses for a time cease, and the heart beat is quicker and stronger.

There are other nerves, part of the autonomic nervous system, called accelerator nerves, connected with the spinal cord below the point at which the vagus branches, that bring impulses to the heart which are opposite in effect to those brought by the vagus. These impulses also start in the medulla; they cause a quickening and strengthening of the beats (Fig. 174). Do the vagus nerve fibers or the accelerator nerve fibers resemble the whip which a driver uses in driving a horse? Which kind corresponds to the reins?

Thus the need of the body for a greater or less active blood supply is regulated by controlling the rate and strength of the heart beats. If the nerves are all in order, the heart beats more slowly when the tissues of the body need little blood, and more rapidly when the tissues need more food or more oxygen. But quickening of the heart beats cannot send more blood through one organ without sending more blood through all the organs, hence it is not so delicate a means of regulating the blood supply as the vasomotor system.

By the nerve mechanism explained in the preceding paragraphs, it is learned that the rate of the heart can be adjusted. The heart rate is not the same for all people. It varies according to sex, size, and age. The average rate in women is 80 beats a minute, in men 70 beats per minute. Tall individuals have a slower pulse than short ones of the same age and sex. This is true also for animals other than man as shown in the following:

Elephant	25–28 beats per minute
Horse	36–50 beats per minute
Rabbit	140–150 beats per minute
Mouse	660–670 beats per minute

The rate is highest in infancy and decreases in adult life. In extreme old age it goes up again. The following indicates the heart rate for different ages:

At birth	140	beats per minute
Infancy	120	beats per minute
Childhood	100	beats per minute
Youth	85	beats per minute
Adult	72	beats per minute
Old age	70	beats per minute
Extreme age	75–80	beats per minute

GLOSSARY

Agglutinin. — A chemical product in the blood which arises as a defense to protect the body from disease-producing bacteria.

The agglutinin has the power of massing the bacteria so that they may be readily ingested by the leucocytes.

Blood pressure. — The pressure which the blood exerts in the blood vessels. It is measured by an instrument called the sphygmomanometer.

Corpuscle. — One of the cells of the blood. We speak of the red corpuscle and of the white corpuscle.

Diastole. — The period in which the heart is not contracting. It includes the time of relaxation of the heart muscles and the rest before the next contraction.

Elasticity. — The property of tissue by virtue of which the part tends to return to its former size or position.

Fibrin. — A substance formed when the blood clots. In the blood is a protein called fibrinogen. When blood is drawn from a blood vessel, the fibrinogen changes into fibrin. The fibrin is a tough, elastic structure and it holds the blood cells in a firm mass. This is the clot.

Friction. — Resistance to motion due to bodies rubbing in contact with other bodies.

Hormone. — A secretion from glands in which the product of the gland is not passed out through a duct, but passes directly into the blood. Sterling invented the name; the Greek word ὁρμάω, meaning to stir up, to excite, was used because of the excitatory properties of the secretion.

Leucocyte. — One of the white corpuscles. It is capable of amœboid movement and ingests bacteria. A leucocyte has a three-lobed nucleus.

Lymphocyte. — One of the white corpuscles. Lymphocytes are of the large and small variety. They have a single, spherical nucleus.

Plasma. — The liquid portion of the blood.

Systole. — The contraction of the heart.

Urea. — A soluble, colorless, crystalline compound, $(CO(NH_2)_2)$. It is formed in the oxidation of protein in the body and is excreted by the kidneys.

Uric Acid. — A white chemical compound composed of carbon, hydrogen, nitrogen, and oxygen $(C_5H_4N_4O_3)$. It results from incomplete combustion in the body. At one time it was thought to be the cause of rheumatism, but it is known now that rheumatism is caused by other conditions.

CHAPTER XIII

THE CIRCULATION OF THE BLOOD (Continued)

I. How the Heart Is Aided in Its Work.
  - By valves in the veins
  - By exercise
  - By the lungs
  - By massage and position

II. The Lymphatic Circulation.
  - How the nourishment gets from the blood into the tissues
  - Lymph
  - The origin and course of the lymphatics
  - What makes the lymph flow
  - The lymphatic glands
  - The spleen

III. Hygiene of the Circulation.
  - The importance of good circulation
  - Taking cold
  - Effects of unusual exercise
  - Sleep and the blood
  - The influence of thought and feeling
  - Clothing
  - Injury to the blood vessels
  - The effect of alcohol
  - The " tobacco heart "
  - Purification of the blood

How the heart is aided in its work. — The heart seems to be constantly at work, but such is not the case. As a matter of fact, the heart occupies nearly as much time in resting as in working. It works for about half a second and rests for about half a second. Yet it does work in a day equivalent to raising a ton of coal nearly two hundred feet. This

work of the heart is aided by the valves in the veins, by muscular exercise, by the lungs, and by massage and position.

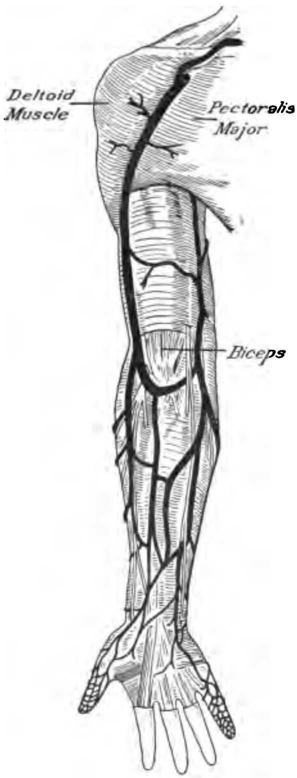


FIG. 136. — The veins near the surface on the arm. Nerves may be seen accompanying the veins. The fibrous sheaths covering most of the muscles have not been removed. The veins of the first three fingers are not shown.

By valves in the veins. — Increase the circulation in the arm by exercising it for a few minutes. The veins in the front of the wrist will then be plainly visible (Fig. 136). The skin and walls of the veins make the blood in the veins appear blue, but it is dark purplish red. (Did you ever see "blue" blood?) Place the tip of the middle finger on one of the large veins; with the forefinger then stroke the vein toward the heart so as to push the blood from a portion of it, keeping the two fingers in place. The vein remains empty between the fingers. Lift the finger nearer the heart, and no blood enters the vein; there is a valve above which holds it back. Lift the other finger, and the vein fills instantly. Stroke a vein toward the hand, and see the blood cause the veins to swell up into little knots where the valves are. (Experiments upon veins are plainest with adults, whose veins are large.) The veins have valves placed frequently along their course. The valves are pockets made by a fold in the inner coat of the wall of the vein (Fig. 137). When you place your hand in your pocket, the latter swells

out; but if you rub your hand on the outside of the pocket from the bottom toward the top, it flattens down. So with the action of the blood upon the valves in the veins (Figs. 138, 139). They all open toward the heart. The valves support a column of blood in each vessel and this support is very valuable in returning the venous blood from the legs.

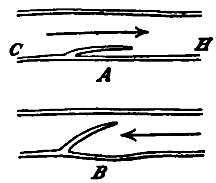


FIG. 137.—Diagram of the valves of veins. *A*, *H*, heart side; *C*, capillary side. The arrow shows the direction of flow. *B*, The valve prevents the flow from going backward.

By exercise.—Suppose a muscle hardens as it contracts and presses upon a vein which goes through the muscle; the blood is pressed out of the vein. The blood cannot go toward the capillaries, for the valves fill and close when it starts that way; so it is all pressed out toward the heart. When the muscle relaxes, the blood that has been pressed forward cannot come back because of the valves, but the valves nearer the capillaries open, and the veins are filled. When the muscle contracts again, the same effect on the blood movement is repeated. We see, therefore, that every contracting muscle acts like a pump forcing the blood through the veins, and when a person works or exercises, many pumps of a muscular kind are working all over the body, aiding the heart in its function (Fig. 140). This aid makes the blood flow faster and relieves the heart of part of its work, so that it beats faster, just as a horse might trot faster if half the load were removed. All of the body gets fresher blood than it got when the muscles

FIG. 138.—Valve in vein distended with blood.

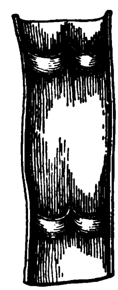


FIG. 139.—Vein laid open to show two valves.

were still and the blood flowed more slowly. This help comes during active work, just when the body is demanding more blood and the heart needs help.

By the lungs.—On inspiration* the lungs help to circulate the blood, since, when they expand and the air rushes into them, the blood as well is drawn toward the cavity of the chest.

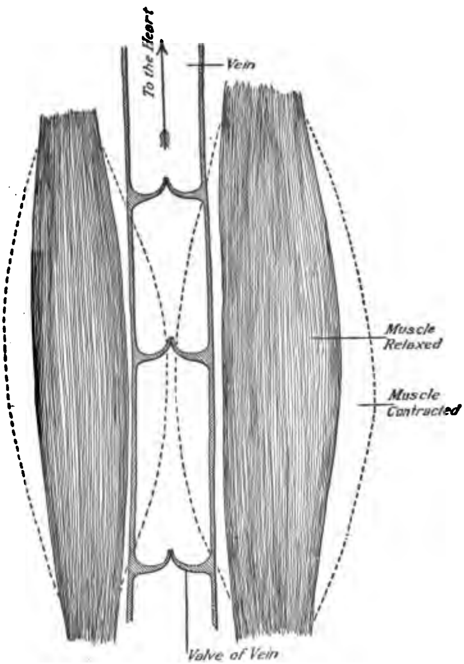


FIG. 140. — Diagram showing effect of muscular contraction upon venous circulation. The valves prevent the blood from flowing in two directions; it can only flow toward the heart.

Does the elasticity of the arterial wall furnish any force to aid the heart? No. When the arteries contract as the pulse passes, it is the force of the heart that is doing it. When you open a door or gate that is closed by an elastic spring, it is the force furnished by you to the spring that shuts the door after you release your hold.

By massage and position.—So effective and necessary is exercise in aiding the circulation, that some people employ others who are skilled in the art called massage, to come regularly and squeeze and knead every muscle like dough. Thus fresh blood is brought and the removal of waste material from the tissues is aided. This

will remove waste material, but such a person misses the tonic effect on the nervous system that comes from participating in sports and activities with other people. The artificial makeshifts of man never include all that Nature would give.

The arteries lie deep under the muscles near the bones, and are likewise pressed upon by muscles, but their walls are much stiffer than the walls of the veins. In fact, many of them in passing through the muscles have tough, fibrous sheaths. It is well that the arteries are not so much affected by exercise, for if they were squeezed by the contracting muscles, the blood would be pressed backward as well as forward since they are destitute of valves, and this would not be favorable to the circulation.

So called "growing pains" in a child are due often to exposure to cold and wet or to falling arches in the feet. These pains may come from overfatigue or may be a slight form of rheumatism. The feet should be examined and if at fault the proper treatment should be given. Massage of the muscles and parts after overwork is beneficial and useful.

Position of the body may aid the flow of blood by overcoming the action of gravity in the large vessels of the legs. The circulation will be assisted by assuming a lying position. After a long walk, or tiring exercise, the circulation will be aided by elevating the feet and legs.

The lymphatic circulation. —The lymphatic* system comprises lymphatic vessels distributed over the entire body, glands located in large numbers throughout the body, especially in the groin and in the armpit, and the spleen, whose exact function is unknown but whose structure is lymphatic in character.

How the nourishment gets from the blood into the tissues. — We left the food and oxygen in the capillaries. How does it get out of them into the tissues? We found that the blood flows very slowly in the capillaries ($\frac{1}{50}$ of an inch per second), and that the capillary walls are very thin, being made

of only the inner of the three coats that make the veins and arteries. Here, then, are two favorable conditions for giving up the nutrition (Fig. 141). We learned that the protein, carbohydrates, and fats were dissolved in the plasma, or liquid portion of the blood. The plasma passes through the thin capillary walls, carrying the food with it. When it gets outside the capillaries, it is next to the walls of the cells that make up the tissues. These spaces are called lymph spaces. Thus the lymph * bathes the cells in the nutritious fluid, and the hungry cells absorb what they need. The oxygen is carried in chemical combination with the hæmoglobin of the red corpuscle.

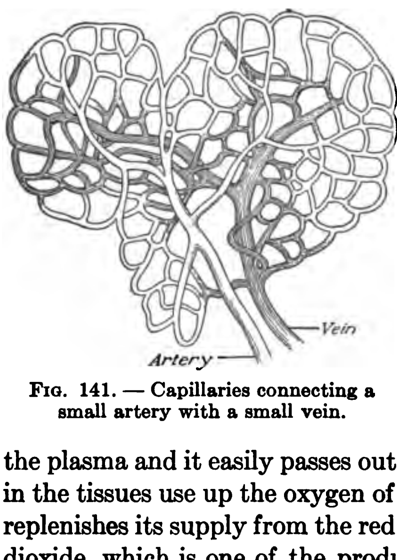


FIG. 141. — Capillaries connecting a small artery with a small vein.

The red corpuscles bearing the oxygen cannot get through the capillary walls. But the oxygen is carried also in the plasma and it easily passes out into the tissues. The cells in the tissues use up the oxygen of the plasma and the plasma replenishes its supply from the red blood corpuscles. Carbon dioxide, which is one of the products of the combination of oxygen with the food material in the tissues, is also a gas. It returns to the heart and to the lungs in the plasma of the venous blood and the lymph.

Why cannot the capillaries themselves carry the food and oxygen into the tissues? Because they are tubes, and as long as the food is in the blood it cannot reach the cells; the capillary walls prevent. The lymph spaces and the lymphatics act as middlemen between the blood and the cells (Fig. 142).

Lymph. — If the plasma kept coming into the tissues without any way of getting back into the blood vessels, the blood would soon be lacking in plasma and the tissues would be oppressed with it. We see, then, the absolute necessity for some provision to get this liquid back into the blood vessels, from which it is constantly overflowing.

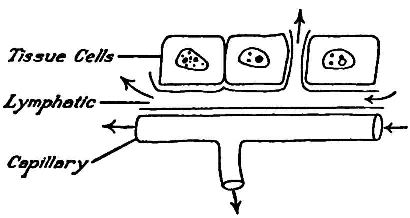


FIG. 142. — Diagram to show function of lymph and origin of lymphatics.

This is done by a system of tubes called lymphatics (Fig. 143).

What is lymph? The blood plasma is called lymph after it gets out of the capillaries. But it soon becomes changed by the addition of substances thrown out by the cells, and by giving up to the cells the digested food brought by the blood. We should have said also that the white blood corpuscles may pass out into the lymph, especially if there is some condition in the tissues that they can correct (Fig. 124).

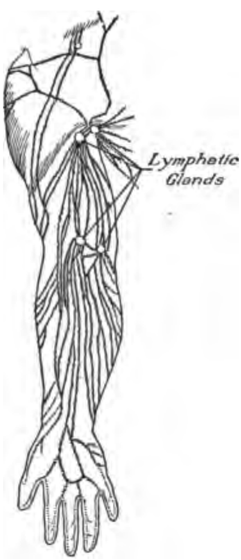


FIG. 143. — The larger lymphatics of the front of the right arm.

We may say, then, that lymph is nearly the same as the blood without the red corpuscles. Did you ever see any lymph? Certainly you have seen it, many times. Whenever there is a blister in the skin from friction, or from a burn, the lymph collects. Sometimes when the skin is grazed, but no blood vessel touched, the lymph may exude.

The origin and course of the lymphatics. — Unlike the blood vessels, the lymphatics, or the tubes which carry the

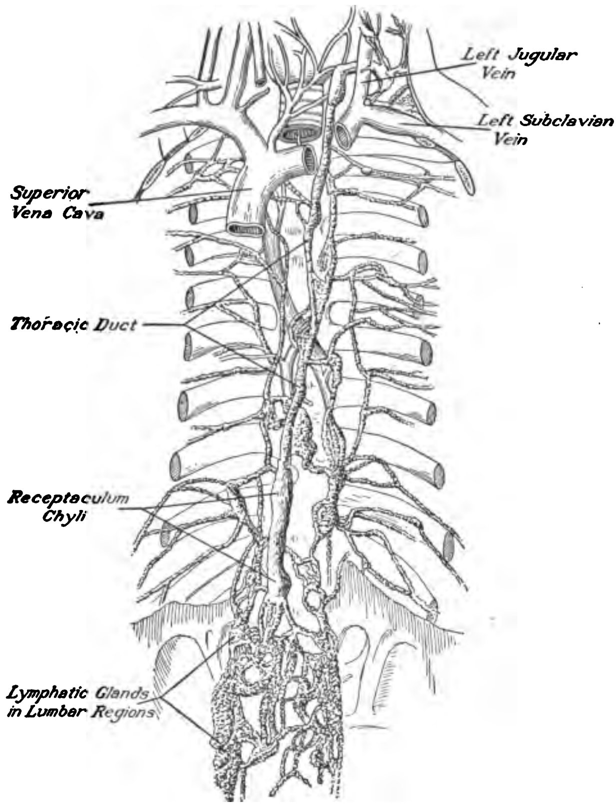


Fig. 144. — The thoracic duct. Note the opening of thoracic duct into the junction of left jugular and left subclavian veins. The connection of these veins with the superior vena cava has been cut across to show the thoracic duct behind it. The lymphatic glands in the lumbar region mark the beginning of the thoracic duct.

lymph, have a beginning. The blood vessels do not begin, but make a never-ending circle. The lymphatics begin in open ends between the capillaries and the cells, or among

the cells themselves (Fig. 142). It will be interesting to learn how they lead the lymph back to the circulation, and what makes it flow, for surely there is no heart for the lymph as there is for blood. When the lymph once enters the open end of the lymphatic, it does not return to the blood, but continues to move slowly or at intervals through the lymphatics on its return to the blood system (Fig. 144). Small lymphatics come together and form larger ones. They continue to unite and form larger ones, until finally the lymphatics from nearly the entire body unite into one large tube, which passes up through the abdomen and thorax, and pours the lymph into the venous system beneath the collar bone near the neck. This largest of all lymphatics is called the thoracic duct.

The thoracic duct is about the size of a goose quill, and empties into the venous system just where the large vein from the left side of the head (the left jugular vein) joins the large vein from the left arm (left subclavian vein) (Fig. 144). We said the lymphatics from nearly all over the body form the thoracic duct; but the lymphatics from the right arm and right side of the trunk and head form what is called the right lymphatic duct, which empties into the right subclavian vein just where the right jugular vein joins the latter. (See Plates.)

What makes the lymph flow. — Did we not learn that something besides the heart makes the blood flow? It is the contraction of the muscles and their consequent pressure upon the veins. The valves in the veins make this pressure effective by allowing the blood to be forced in only one direction. It is likewise found that the lymphatics have valves, and that they are more abundant than those of the veins. Whenever the muscles contract, the lymph is forced along, and the valves provide that no progress made shall be lost by any backward movement. Every pressure leaves a part of the lymphatic empty and ready to fill from behind

(Fig. 145). Also, if the body is pressed upon or shaken, as when riding a trotting horse, or in a jolting vehicle, the lymph is moved beyond the valves at every jolt, and its circulation aided.

FIG. 145. — A full lymphatic with its valves distended (cut open).

The secret of the powerful effect of muscular work upon the health lies chiefly in the great aid that it gives the lymphatic and venous circulations. The importance of an active lymphatic circulation is seen when we remember that the blood does not make its exchange directly with the cells of the tissues, but with the lymph, and the lymph makes the exchanges with the tissue cells.

The lymphatic glands. — Along the course of the lymphatics, numerous enlargements occur called lymph nodes * or lymph glands (Fig. 146). They consist of a connective tissue framework, the meshes of which are crowded with lymph cells. The lymph in its course must filter through these clusters of cells, and, in doing so, is purified; for the node cells take up impurities in the lymph, and work over and change their nature. The cells in these nodes multiply, and some of them are taken up by the lymph and carried into the blood to become those remarkable little bodies, the white blood corpuscles. It is a curious fact that the older white corpuscles are broken up in the lymph nodes, and their remains are absorbed by the newly

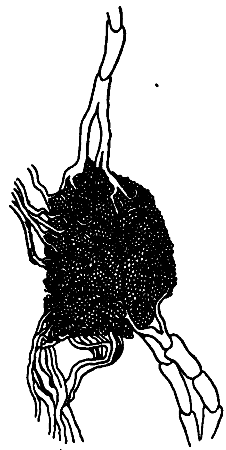


FIG. 146. — Lymphatic gland. Showing valved lymphatics entering and leaving it.

formed white corpuscles, just as the latter absorb germs and other foreign particles that may enter the blood. The lymphatics penetrate and help in the nourishment of every tissue, even in that of the bony tissue.

The spleen. — This organ resembles the lymph nodes. It is purplish red, about five inches in length, and is situated just inside of the lower ribs on the left side of the abdomen. White corpuscles are formed in it as well as in the smaller lymph nodes. In it also the red corpuscles that have finished their service in the blood are probably broken up and destroyed.

Hygiene of the circulation. — Have you learned yet the curious fact that all of the living cells of the body live under water, just as the amœba does? The lymph and the blood are chiefly water and the cells are all bathed continually in one or the other. The blood bathes the cells in the walls of its vessels, and the lymph, or the blood without the red corpuscles, is found filling the interstices or spaces between the cells, like water in a sponge. From the spaces, as we learned, it is taken by the lymphatics in order to make room for fresh lymph, free from waste material and bringing fresh nourishment. The only exception to the rule that the cells live a watery existence, is found on the surface of the body; the cells of the outer skin, hair, and nails, however, may be called dying cells, for they are not alive in the same sense that the other cells are: they do not contain nuclei and cannot repair themselves or grow.

The importance of good circulation. — The supreme, the transcendent importance to the health of the tissues, of pure blood and good circulation, now becomes apparent. All that the cells need, in order to be sound and vigorous, is to have good food and oxygen brought within their reach, and to have the waste material, or products of combustion, removed; the circulation meets these needs.

When unsoundness occurs in any part of the body, there

is a strong probability that the circulation there is defective. The hair is lost by cutting off the circulation from the scalp. The eyes may become inflamed, or the lids diseased, because of obstructing in the neck the return of the blood from the head; improper neck clothing or stiffened muscles may cause this obstruction. Indigestion may result if vigorous mental or physical activity, just after eating, draws the blood away and prevents the secretion of the digestive fluids. Gout may occur from the deposit of waste materials in the spaces around the joints where the pressure from the circulation is least. Colds occur when the blood vessels in the walls of the air passages become congested or swollen with blood, and the vessels lose their tone so that they cannot contract and keep the blood moving onward.

Pure blood is just as necessary as free and unimpeded circulation. We shall learn later how the digestive organs serve to furnish the nutrition, how the lungs furnish the oxygen, and how the skin, kidneys, and lungs remove from the blood the impurities and waste materials.

Taking cold. — Sudden or prolonged exposure to cold while the muscles are inactive, so stimulates the surface blood vessels through the vasomotor nerves that they become tightly contracted and send the blood to the interior of the body. It accumulates there and may cause such congestion of the mucous membrane of the nose, throat, windpipe, or lungs, that inflammation ensues. A cold is an inflammation of the mucous membrane of part of the air passages. Rapid cooling off from a heated condition, especially if one is in a profuse perspiration, may cause the same results; or, exposure to moderate but continuous cold without exercising may bring on a cold. Sitting on the damp ground, sitting with damp feet, sitting for a long time in a cool draught, or going thinly clad in cool weather, may cause a cold; only foolish persons think they are so hardened as to withstand such risks without injury.

A person may be in the habit of coddling himself by living in overheated rooms, or by wearing too warm clothing and by constant use of mufflers on going out; his surface nerves thus become so delicate and the blood vessels of the surface so relaxed, as to insure taking cold on every accidental or unavoidable exposure. A better plan is to keep the house cool, the thermometer standing at 65° to 68°, sleep with open windows, take cool baths, and keep warm when out of doors by walking or exercising briskly. Thus the blood vessels are toned up, the circulation is made vigorous and steady, and the person is better fitted to withstand the ordinary conditions of life without disease continually recurring owing to deranged or weak circulation. Any process of "hardening to cold" that is not accompanied by vigorous exercise is a risk to the health.

The reciprocal action of the blood vessels of the skin and the internal organs is sometimes illustrated when a person drinks freely of cold water. There is a sudden breaking out of perspiration. Why is this? Certainly the water does not reach the skin so quickly. The cold in the interior stimulates the internal vessels to contraction and the blood is diverted to the unstimulated vessels of the skin, surrounding the sweat glands.

Effects of unusual exercise. — If a person has sedentary habits and has neglected active exercise for some time, the heart, as well as the other muscles, becomes weak. If such a person hurries to catch a train, or takes very rapid and trying exercise of any kind, he may bring on an unpleasant palpitation of the heart, which is a warning to desist at once. Violent exercise should not be taken until one has gradually led up to it.

Sleep and the blood. — A person who loses much sleep becomes pale; the paleness is evidence of a diminution in the number of red corpuscles. It is during sleep that the corpuscles that have been worn out during the day are replaced,

but loss of sleep causes a greater loss to the blood than usual, with less than the usual opportunity for repair.

The influence of thought and feeling. — Rage excites and strains the heart. The experience of great emotion, either of joy or anger or fright, often raises the blood pressure so much that a vessel is broken and death occurs. Calmness and poise* are mental qualities that have desirable effects upon the circulation.

Clothing. — The blood cannot circulate with perfect freedom unless the entire body is so loosely clothed that there is no pressure upon any of the blood vessels, no interference with the lungs as they expand, no pressure upon the stomach, liver, and intestines. Many of the largest veins, particularly those of the arms and legs, lie so near the surface that any tightness of the clothing is certain to diminish the flow of blood through them. Sleeve supporters and garters, if used at all, should be of weak elastic with adjustable buckle, and no tighter than is absolutely necessary. It is especially necessary to keep the extremities warmly clad and dry.

Injury to the blood vessels. — To perform effectively the work of transporting the blood, the vessels must remain whole, and they must keep their shape and elasticity. Injury of the vessels may occur by cutting of the vessel wall or by changes in the wall so that it loses its shape or elasticity.

Hemorrhages. — Hemorrhage is a flow of blood from an injured blood vessel. When the wound is slight, the clotting of the blood stops the flow. Clotting is rapid in the blood of healthy persons and slow in the blood of poorly nourished persons. Blood does not spurt from a cut vein but flows in a slow stream. When an artery is cut, the blood comes forth in a jet, with stronger spurts at each throb of the heart. In a large artery the pressure is so strong that it forces away the clot as fast as it is formed, so that death may result from loss of blood.

Varicose Veins. — Varicose veins are enlarged and tortuous veins. This condition occurs more frequently in people who take little exercise, who follow occupations in which they stand still for long periods, as motormen and clerks. Postmen who are on their feet a great deal but very active rarely suffer from varicosities.* Why is this so? Has muscular contraction anything to do with the circulation of the blood (Fig. 140)? Tight garters should not be worn, because they prevent the venous flow by constricting the part.

Hardening of the Arteries. — Hardening of the arteries occurs in late adult life and seems to be caused by intemperate living. Too much physical work, too much mental work, too much work for the digestive organs, may produce a hardening of the arteries. The loss of elasticity is caused by an accumulation of salts in the wall of the artery. The salts make the artery hard. It becomes, therefore, less able to adjust to changes in pressure, and it will break more easily.

The effect of alcohol. — It is believed that the white corpuscles are injured by alcohol in the blood, and that they lose to some extent their activity in attacking poisons and germs of disease. This gives an explanation of the susceptibility* of drinking men to germ diseases. Persons accustomed to use alcohol are usually the first victims of cholera and of yellow fever; while some abstainers, under constant exposure, remain untouched. The white corpuscles repair cuts and broken bones; hence intemperate persons do not recover from accidents and surgical operations as quickly as do total abstainers.

The "tobacco heart." — Tobacco, unlike alcohol, does not dilate the blood vessels of the skin; tobacco users are often pale from want of blood in the skin. We thus see why tobacco users develop a stronger craving for drink than non-users, because the alcohol has, in some respects, an effect

opposite to that of tobacco. However, heart action is temporarily increased when tobacco is used. In the previous chapter you learned that the accelerator * nerves increase the heart action and the vagus nerves (inhibitory *) hold it in check. The vagus is partially paralyzed by tobacco, and the heart beats with more force, thus exhausting itself. The pulse of the habitual user shows unmistakably the injury done to the heart. It loses the firm steady beat of health and becomes irregular. Most of the time its beat is feeble; for a period its beat may be rapid and palpitating. This condition is known to physicians as the "tobacco heart."

Physicians who have made a special study of the subject, claim that one out of every four tobacco users has the tobacco heart. It prevents success in athletic contests and feats of strength. It prevents a large proportion of the young men who apply for enlistment, from entering the army. Knowing the paramount importance to sound health of rich blood and perfect circulation, we are not surprised to know that the whole body is enfeebled by tobacco, and that mental as well as physical vigor is impaired. Observant teachers can often tell which of the boys in school are addicted to the use of tobacco from the comparative inferiority of their appearance and from their indolence of body and mind.

Purification of the blood. — The impurities of the blood are the waste substances which result from the chemical action occurring in the body cells. This waste material is removed from the body if the circulation is adequate and if exercise is sufficient. The blood is freed from these impurities by the lungs, by the sweat glands of the skin, and by the kidneys. This process of blood purification is natural, and will at all times suffice, if the individual drinks enough water, avoids constipation, and exercises sufficiently. Therefore, patent medicines which claim to "purify the blood" are never necessary, if one follows the natural laws of health.

Furthermore, the claim of purification is false and they never accomplish their purpose. *Patent medicines are made to sell and not to accomplish any particular result in the body.*

Activity is the most necessary condition for the health of a cell. In every cell is found matter in three conditions: that which is actually living, that which was recently living, and that which is about to live by being transformed in the cell. The transformation from lifeless to living, and from living to dead, and the removal of dead matter must go on promptly. Anything which interferes with this activity interferes with the health of the cells. When life is natural and complete, all the organs are given work to do and are healthy, active, and strong; there is a feeling of buoyant happiness, the mind is clear, the will is firm, and the man truly lives. Therefore, pure blood will be available for the ceaseless activity of the cells if proper and sufficient exercise is taken.

APPLIED PHYSIOLOGY

Exercise I

1. The main arteries run down the middle of each limb close to the bone on the side toward which the limb bends. Why do they have this position?
2. Where is the thickest wall of the heart? Why? The thinnest walls? Why?
3. Why do we need warmer covering when asleep than awake?
4. When would it be pleasant to throw off a coat or cloak, but imprudent to do so?
5. If the clothing has been accidentally wet and the wet garments cannot be changed for dry ones at once, how can one keep up a good circulation to prevent taking cold?
6. When cold air strikes it, why does the face first blanch and then flush?
7. When a person is warm-hearted in the usual sense of the term, is it also true physiologically?
8. When do dark veins in the wrist show most plainly? Of what is dark blood in the body in general a sign?

9. Why does a hot foot-bath sometimes relieve a headache? Why should it relieve a cold in the head?

10. How is the blood purified?

Exercise II

11. Tight clothing at the waist may cause too much blood in what parts? Does it tend to make the circulation sluggish or active?

12. Which is more compressible, a vein or an artery? Does a tight garter interfere more with the flow of blood to the feet or from the feet?

13. Why are varicose veins so often found in the lower leg?

14. Why may a sluggish circulation through full veins in the feet as well as want of blood in the feet cause them to be cold?

15. Why are students very likely to have cold feet?

16. Why does the body of a person dying by drowning or strangulation turn blue?

17. What would you do in the case of a severe wound in the absence of a surgeon?

18. What is the object of a collar? Why is it, therefore, not necessary to have the collar as high in front as behind? Why is it unhealthful to have it so? What is the purpose of a cuff?

19. What is the most serious injury of alcohol to the blood?

20. In what part of the circulation does the so-called venous blood flow through arteries?

Exercise III

21. Show how life comes by death.

22. Can any physiological basis be given for the claims of patent medicine venders that their nostrums "purify the blood"?

23. What vein begins and ends with capillaries?

24. What artery takes arterial blood to an organ where it is still further purified, yet is called venous blood when it leaves the organ? (As it leaves that organ the blood is the purest in the body. See Plate VIII.)

25. What keeps the blood in circulation between the beats of the heart?

26. What are the functions of the capillaries?

27. Why is a cool draft in the house more apt to cause a cold than a cool wind out of doors?

28. Why do we perspire freely after drinking freely of cold water?

29. What causes the difference between the hard hand of the blacksmith and the soft hand of the clerk?

30. Why does rubbing wear out the leather of the shoe, but the friction of the shoe upon the toe cause the skin to grow thicker and to form a corn?

31. What is the effect upon the circulation of horseback riding?

LABORATORY EXERCISES

Experiment 1. To demonstrate circulation, vasomotor control and blood pressure.

Arrange an inverted bell jar (Fig. 147) on a support and connect it with a series of glass pipes arranged in an upright position. For

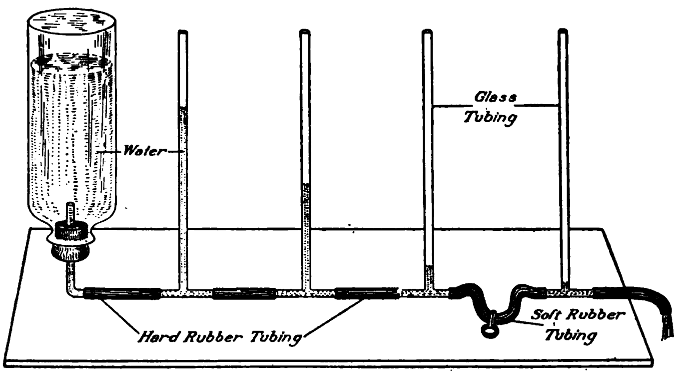


Fig. 147.

the connections use a hard rubber tubing. Before the last two pipes insert a section of soft rubber tubing and attach a clamp which will allow graduated pressure to be made on this section of the circulation. Fill the bell jar with water colored with carmine and notice the following:

1. Name the heart, the arteries, the capillaries, and the veins.
2. Have the clamp entirely free and observe the effect upon the flow of water. How high does the liquid rise in the tubes? Mark the point in each case.
3. Close the clamp down so that no liquid flows from the venous end. How high does the liquid rise in the tubes? In which tube

is it highest? Is this the tube that corresponds with the arteries nearest the heart?

4. Open the clamp enough to have the liquid flow from the venous end in a slow and constant stream. Notice the change in the height of the liquid in the tubes. What are the points of difference between the effect seen in (1) and (2)? Would you say that the pressure decreased from the heart to the capillaries and that in the venous system the pressure was very low until in the last tube it was practically at zero?

When the capillaries are shut down, what effect has that on the blood pressure? Is the resistance to the flow of blood increased? How is such effect produced in the body?

Experiment 2. To study the heart rate in exercise.

Material. — Watch with a second hand.

Method and observation. — (*a*) Palpate the pulse in the radial and temporal arteries, feel with the tips of the first and second fingers. What causes the pulsation? (*b*) Count the radial pulse during consecutive 15 second periods (one quarter minute) and when the rate in any two successive ones are alike, take that rate as the rate of the heart for the time and activity. Find the heart rate per minute in the following:

1. Horizontal position, face up.
2. Horizontal position, face down.
3. Sitting position.
4. Standing position.
5. After 10 deep knee bendings.

Does the rate vary? Why?

Experiment 3. To study the heart rate in respiration.*

Material. — Watch with a second hand.

Method and observation. — Count the radial pulse and obtain the rate as described in experiment (1). With that procedure obtain the heart rate during the inspiratory phase and the expiratory phase. Is the rate different? In which is it faster?

Experiment 4. To study the heart rate in exercise and respiration.

Material. — Watch with a second hand.

Method and observation. — Count the heart rate in the standing position. Perform twenty deep knee bendings and count the heart rate at once at the end of the exercise. Notice the difference during the inspiratory and expiratory phases of the respiration.

GLOSSARY

Accelerator. — A mechanism that increases the speed of an organ. Applies to the nerves which go to the heart and increase the rate of contraction of that organ. There is an accelerator center.

Expiration. — The act of breathing out. It comes from the Latin, *ex* meaning out, and *spiro*, to breathe.

Inhibitory. — A mechanism that checks the activity of an organ. The effect is opposite to that produced by the accelerator nerves or center. The inhibitory nerves of the heart are the vagi.

Inspiration. — The act of breathing in. Its derivation is similar to the derivation of expiration.

Lymph. — The fluid that bathes the cells and lies in the spaces between the cells. It is carried to the heart by the lymphatics. It is derived from the plasma of the blood.

Lymphatic. — A tube composed of thin cells and serving to carry the lymph from the cell and tissue spaces back to the heart.

Lymph nodes. — Small glandular structures situated along the course of the lymphatics and especially numerous at the joints. They serve to take out of the lymph, poisons that would injure the body.

Poise. — Balance, equilibrium.

Respiration. — The act of taking in and breathing out air.

Susceptibility. — The condition of yielding or succumbing readily. Resistance is the opposite quality. One who has little resistance shows susceptibility.

Varicosity. — A condition in which the veins are dilated, twisted, and tortuous.

CHAPTER XIV

THE RESPIRATION

I. Why Breathing Organs are Needed.
II. The Respiratory Organs.
  The nose, throat, larynx, and trachea
  Bronchial tubes
  Lungs
  The diaphragm and other muscles
III. The Breathing Process.
  Inspiration
  Expiration
  Ease in breathing
IV. The Air We Breathe.
  Composition of the air
  Foul and fresh air
V. The Hygiene of Respiration.
  Breathing through the nose
  Muscular action in breathing
  Respiratory exercises
  Ventilation
  The effect of tobacco on the respiratory organs
  General considerations

Why breathing organs are needed. — Every cell in the body requires oxygen to enable it to do its appointed work. When the supply of oxygen stops, the activity of the cell ceases at once. If it is a muscle cell, motion can be generated in the muscle only by the union of oxygen with the contents of the cell. If it is a gland cell, it cannot do its work of secreting useful fluids without the help of oxygen, for the substances which the gland cell takes from the blood must be

changed to form the secretion. If the cell is a brain cell, although it may not use as much as a muscle cell uses, oxygen is still indispensable. The oxidation that takes place in the various cells results in the formation of carbon dioxide and other waste products which would destroy the life of the cell if allowed to remain; these are removed from the body by the same organs that supply the oxygen. How does the amœba get its oxygen?

The respiratory organs. — It is obvious that in animals of large size with many tissues, the great majority of the living cells of the tissues must be buried deep away from the external surface. But even if deep-seated and away from the air, the living cells have the same need of oxygen as though near the surface. If oxygen is supplied to the blood, the latter conveys the oxygen to the cells; but it is seen that a very efficient organ is needed to supply the blood with oxygen sufficient for so many cells. The breathing apparatus varies in different animals; (1) it usually consists of a device for exposing to the air a great amount of thin tissue, which is a specialized form of the outer skin of the animal (if the animal is not a land animal, the tissue is exposed to the water); (2) the animal is further provided with means to keep up a current of air (or water) on the outside of this modified skin and a current of blood on the inside. Large animals with many deep-seated and inaccessible cells require for sufficient oxygen a large respiratory area. This is provided by having it folded as indicated in Figure 148. In man, it has been estimated that by the finer and finer division of the air

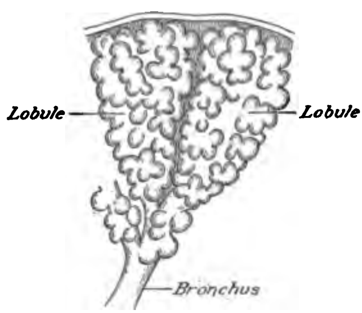


FIG. 148. — Two lobules at the end of a bronchial tube.

sac, a pair of human lungs presents to the air a surface of at least one hundred square feet (or ten feet square); (3) the remainder of the breathing apparatus consists of muscles for changing that air that is in contact with this great surface.

Nose, throat, larynx, and trachea. — The air usually passes in at the nose and returns by the same way, except during talking or singing. If you look in your mouth with a mirror, you will see at the back part an arch which is the rear boundary line of the mouth. Just above the arch is likewise the limit for the back part of the nasal passages. The funnel-shaped cavity beyond, into which both the mouth and nasal passages open, is called the pharynx (far′inks), or throat. Below, two tubes open from the pharynx, one into the trachea (trak′e-a) or windpipe, the other into the esophagus, or gullet. At the top of the trachea (Fig. 149) is the cartilaginous larynx, or voice box, and the opening from the throat is provided with a lid, the epiglottis, also consisting of cartilage. The larynx will be described more fully in treating of the voice; it may be felt as the Adam's apple. Just below it comes the trachea proper which is a tube about three fourths of an inch in diameter, and about four inches long (Fig. 149). It con-

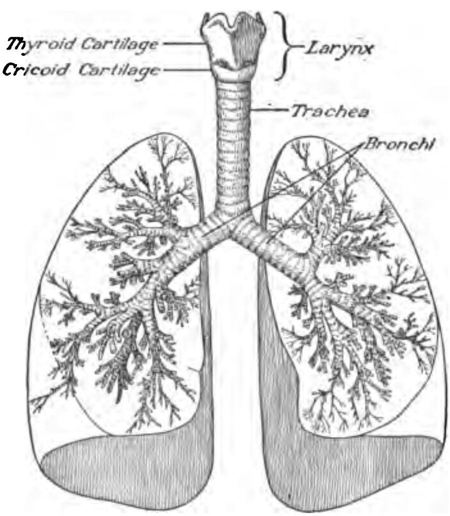


FIG. 149. — Not all of the divisions of the bronchi are shown, but notice how these tubes by the finest branches extend to all parts of the lungs.

sists of hoops of cartilage which are not complete circles but are shaped somewhat like the letter C, being completed behind by nonstriated (involuntary) muscular tissue, whose function is to draw the ends of the rings together at times, *e.g.* during coughing, and reduce the caliber of the tube. The function of the hoops of cartilage is to keep the windpipe open at all times. If it should collapse under pressure, life might be lost. These rings of cartilage may be felt in the neck.

Bronchial tubes. — The lower end of the trachea is just behind the upper end of the sternum; and there it divides into two bronchi, called the right bronchus and the left bronchus (plural, bronchi). The bronchi subdivide into a great number of smaller branches, called bronchial tubes. Cartilage is found in the walls of all but the smallest of the tubes. The subdivision continues until the whole lung is penetrated by branches, all having the general name of bronchial tubes (Fig. 149). The smallest are only about $\frac{1}{75}$ of an inch in diameter. They ramify through the lungs, somewhat like the branching of a tree, each tiny tube finally ending in a wider funnel-shaped chamber called a lobule (Fig. 148), into which so many dilated sacs, called air cells, open that the walls of the terminal chamber, or lobule, may be said to consist of tiny cups, or air cells, placed side by side. (The word " cell " is here used in its original sense to denote a cavity or chamber, and not in the sense of a protoplasmic cell.)

Lungs. — The lungs are elastic air-containing organs constructed of epithelial cells of several kinds and blood vessels. The air cells are arranged to allow air to come readily into contact with the blood, and to remove from the lining the dust and dirt that has come in with the air. The numerous blood vessels afford means of rapidly moving the blood through the lungs. The elastic nature of the lungs provides for easy and quick inflation. These characteristics

are best understood by studying the internal and external structure.

Internal Structure. — The wall of an air cell consists of elastic connective tissue lined with a layer of very flat and thin epithelial cells (Fig. 150). This lining is continuous with the epithelial lining of the bronchial tubes. It is so thin as to offer almost no obstruction to the passage of oxygen out of the cell and the entrance of the carbon dioxide from the blood vessel (Fig. 151).

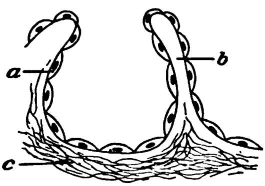


Fig. 150. — The wall of an air cell. *a*, the epithelium; *b*, partition between two air cells, in which the capillaries lie; *c*, fibers of elastic tissue. Notice *b*, and name the structures through which oxygen and carbon dioxide must pass.

It must be remembered that mucous membrane lines all cavities in the body accessible to the air. Almost all of the nose and pharynx, and all of the trachea and bronchial tubes, as far as the lobules, are lined with a mucous membrane the cells of which are furnished with cilia (Fig. 152). These are minute hairlike filaments which are in constant motion. When a few of the cells are examined under a microscope, we may see the cilia in motion, even for a time after the removal of the cells from the body. They make a quick stroke upward, and move back more slowly, and this is found to give them the power of moving

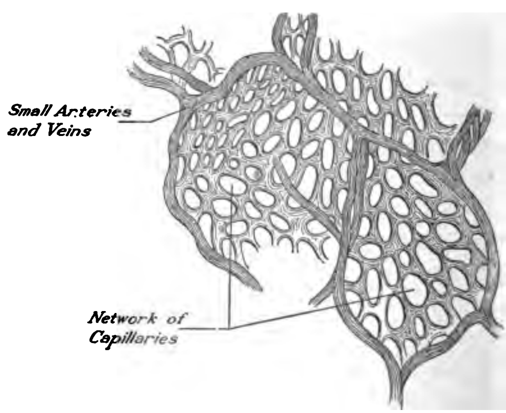


Fig. 151. — The blood vessels around two air cells.

particles of dust which enter the lungs upward toward the larynx. Upon reaching the larynx, the dust brings about irritation which causes it to be coughed up. In the nasal passages, they serve a similar purpose. At the opening of the nostrils are also placed ordinary hairs (hundreds of times larger than cilia), which aid in cleaning the air of dust as it enters the nose.

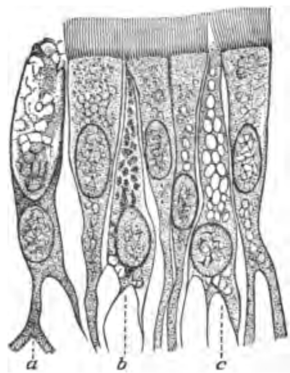


FIG. 152. — Ciliated cells from the trachea of a rabbit, highly magnified. *a*, *b*, *c*. mucous cells in various stages of secreting mucus.

Near where the trachea divides into the two bronchi, the pulmonary artery, bringing the dark blood to the lungs, divides into two branches, and the subdivision continues, until, finally, a network of capillaries is formed around each lobule, or cluster of air cells. These capillaries are the termination of the branches of the pulmonary artery, and the beginning of the pulmonary veins. It is here that the blood changes from a purplish red to a scarlet red. A fine connective tissue holds together all these air cells and tubes.

External Appearance. — The entire cavity of the chest except the space occupied by the heart and a few of its blood vessels and the esophagus, is filled by the lungs and their coverings. The lungs are light pink in early life but become grayish and darker as age advances. This change is more marked in persons who dwell in large cities or where the atmosphere is smoky and dusty. The lungs, or a part of one, will float if thrown upon water. The right lung has three lobes, or divisions, and the left, two lobes. The general substance of the lungs consists of bronchial tubes, blood vessels, lymphatics, and air cells, as above described, the air cells being chiefly near the surface.

The surface of the lungs is in contact with the chest wall, but it is not attached to the chest wall. It is held in contact by the negative pressure* within the chest cavity. This negative pressure during respiration varies from 755.5 mm. of mercury on expiration to 752.5 mm. of mercury on inspiration. Its negativity therefore increases during inspiration. Imagine a closed bag or sac made of thin membrane lining the whole of the chest. Now imagine another closed sac a little smaller, that is inside of, and lining, the first one. Next imagine the lungs to be found inside the inner sac. Here we have the lungs within the two membranes, called the pleuras. The pleuras are in contact, so that the lung may be said to be in contact with the chest wall.

The outer pleura lines the chest wall, the inner pleura covers the lungs. The two membranes form between them a closed sac, a serous cavity which is air-tight and aids the lungs in following the chest wall without friction when the chest expands. The two pleural surfaces are in contact, and secrete just enough fluid to enable them to glide smoothly upon each other. But for the pleura there would be friction between the lungs and the chest walls.

The diaphragm and other muscles (Fig. 153). — The floor of the chest cavity is formed by a muscle that is the broadest in the body, and also the thinnest in proportion to its width. It is called the diaphragm. It rounds up under the concave base of the lungs somewhat like a dome and separates the thoracic and abdominal cavities. It is attached to the lowest ribs at the sides and to the lumbar vertebræ behind (Fig. 153). Its rounded side is turned toward the chest, and its hollow side toward the abdomen. It is the most important muscle of the respiratory system. When it contracts, it flattens and descends, and the lungs descend with it, thus lengthening and enlarging the cavity of the chest from top to bottom.

When the diaphragm descends, it acts as a piston or a

tight-fitting round board would act if pressed down into a barrel of water. If there were two holes in the board (cor-

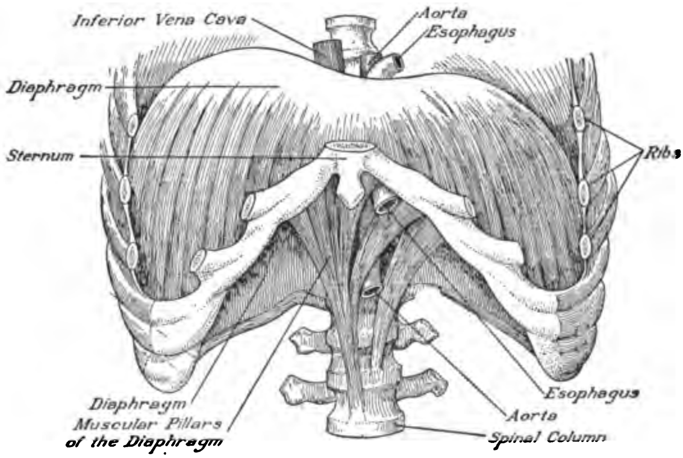


FIG. 153. — The dome-shaped diaphragm. Name the large tubes which pass through the diaphragm.

responding to the vena cava and the thoracic duct), the water would be pressed up. Thus the circulation is aided

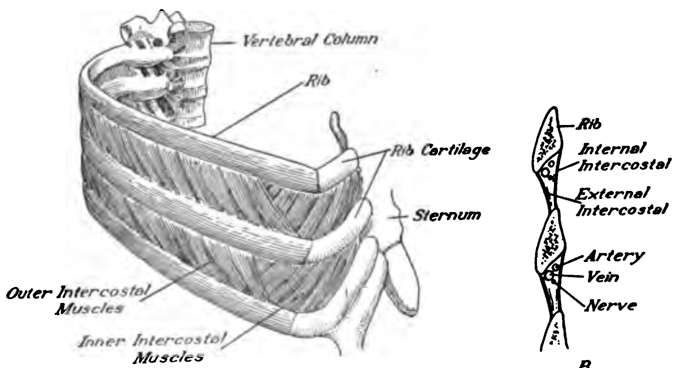


FIG. 154. — Figure A, showing three ribs, their attachment to spine and sternum, and the muscles completing the thoracic wall. In *B*. the structures between the intercostals are shown.

by breathing. When the diaphragm relaxes, its thinness and flexibility would allow it to drop downward, instead of springing upward as pupils sometimes suppose; but the abdominal walls contract as the diaphragm relaxes and force the liver, stomach, etc., against the diaphragm, thus pressing it against the lungs (Figs. 155, 156).

The chest walls can be lifted out at the sides and in front. This is accomplished by muscles leading from the shoulders and spinal column to the outer surface of the ribs, and by the intercostal muscles, or the muscles that connect each rib with the rib above (Figs. 154). Thus the chest may be made deeper from front to back and from side to side, and if the diaphragm acts at the same time, the chest is elongated from top to bottom, and thus is enlarged in all directions.

The breathing process. — The breathing process serves to carry into the lungs oxygen for the blood and to expel the excess carbon dioxide given up to lung air by the blood. The passing of the air into the lungs is called inspiration, and the passing of the air out from the lungs is called expiration. The two together constitute respiration, or breathing.

Inspiration. — The lungs themselves contain no muscular tissue, and therefore, they cannot expand by any force of their own. Yet they expand when the chest expands. How does the enlargement of the chest cause the lungs to expand, and the air to rush in? The air cannot be pulled in, for it has no cohesion, its parts do not stick together. It is found that the air has considerable weight, for the height of the atmosphere* is at least forty miles, and the air above is pressing down on that below. When the chest walls are moved outward against the weight of the outer air (Figs. 155, 157), the space in the chest is increased, and the air already in the chest expands to fill the greater space. The air, when expanded, is lighter, and exerts less pressure than before, and the denser air outside, having greater pressure, presses inward until the

air in the lungs is as dense as it was before the lungs were enlarged. Thus do we allow the air to come into our lungs; we do not draw it in but make space for it, and the atmosphere outside presses it in.

Expiration. — This is the reverse of inspiration. The space within the chest is diminished, and the air in the lungs

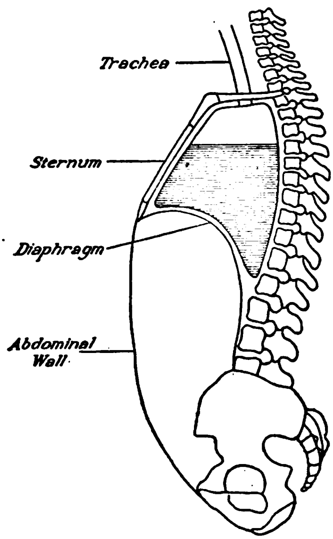


FIG. 155. — Inspiration.

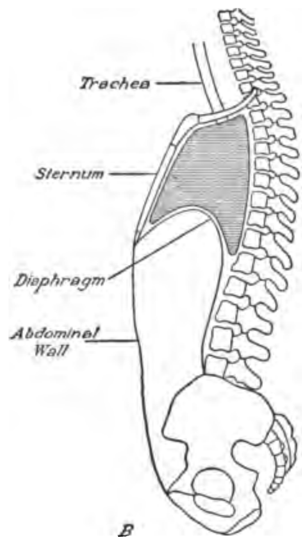


FIG. 156. — Expiration.

Diagrams to show the positions in respiration of the sternum, diaphragm, and abdominal wall.

is compressed and becomes denser than the air outside. This denser air has greater pressure than the outside air, and presses out through the air passages until enough has passed out to restore the equilibrium, making the pressure equal without and within (Fig. 156).

In ordinary quiet expiration, the lungs become smaller, owing chiefly to the elasticity of the parts involved. When the air rushes in during inspiration, it fills the enlarged

air cells and the walls being made partly of elastic tissue, the cells contract again when the muscles of inspiration cease to act. When the ribs are lifted up during inspiration, the costal cartilages that connect them with the sternum are slightly bent, and the elasticity of these cartilages, as well as the weight of the chest wall, causes the ribs to become lower when the muscles of inspiration cease to act. Many pupils get the erroneous idea that the diaphragm is also elastic and pushes upward when it relaxes, thus aiding expiration. When relaxed, it has no more elasticity than a piece of cloth, and no power to push itself upward. It should be remembered that muscles never push; they always pull by drawing their origin * and insertion * nearer. However, the abdomen has been somewhat compressed, and its walls somewhat stretched during the inspiration. When the diaphragm relaxes, the elasticity of the muscular walls of the abdomen presses the organs against the under side of the diaphragm, pressing that in turn against the base of the lungs, and aiding expiration.

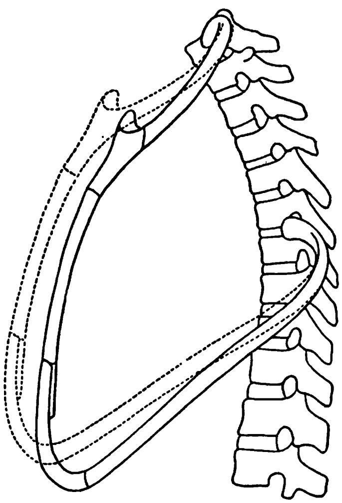


FIG. 157. — Diagram of first and seventh ribs, in connection with the spine and the sternum, showing how in inspiration the latter is carried upward and forward. The expiratory position is indicated by continuous lines, the inspiratory by broken lines.

Quiet or passive expiration is, therefore, a rebound brought about by the elasticity of the air cells, costal cartilages, and abdomen, and by the weight of the chest wall. Active expiration adds muscular contraction to the above forces.

The two layers of intercostal muscles are among those used in inspiration and active expiration (Fig. 158). When the upper ribs are held, the contraction of the intercostals raises the ribs; when the lower ribs are fixed, the contraction depresses the ribs. The intercostals act to raise or depress the ribs, depending upon the fixation of the ribs above or below. In active expiration the abdominal walls contract and press the abdominal organs against the diaphragm, thus pressing upward on the lungs.

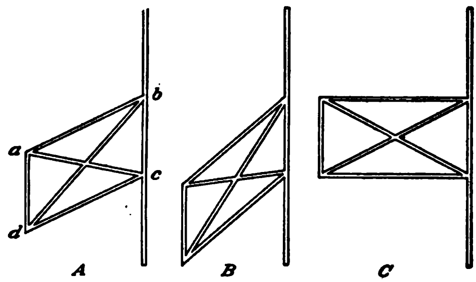


FIG. 158. — Diagram to show action of intercostal muscles on inspiration and expiration. At *A* two ribs (*a–b* and *d–c*) are represented in passive position. The two ribs move at the fixed points, *b* and *c*. When the ribs are raised notice that the line *a–d*, which represents the sternum, is farther from the spine *b–c*, as in *C*, and nearer when depressed, as in *B*. This obliquity of the ribs permits the increase in the depth of the chest on inspiration and decrease in expiration.

Ease in breathing. — By studying the skeleton of the chest, carefully observing the bones and cartilages, and by experimenting upon his or her own breathing, the pupil is to fill out the following reasons why expansion and contraction of the lower chest (abdominal breathing) is easier than breathing with the upper chest (costal breathing).

1. There are two pairs of —— ribs below, while there are none above.

2. There are three pairs of —— ribs below, while there are none above, but all the ribs of the upper chest are —— ribs.

3. The joints between the seven pairs of true ribs and the sternum are more flexible below because ——.

4. In abdominal breathing the breaths will not have to be

so frequent to supply the same amount of air, because the lower chest, besides being more flexible, is —— than the upper chest.

5. The bones of the —— rest upon the upper chest. In upper chest breathing their weight, and the weight of both of the ——, must, therefore, be lifted. (Test by experiment.)

The air we breathe. — Air is composed of a mixture made up chiefly of oxygen, nitrogen, and a very small quantity of carbon dioxide. Nitrogen is colorless, tasteless, and odorless; it does not support combustion, and is one of the most inactive gases known to chemists. The oxygen of the air is also colorless, tasteless, and odorless, but it is one of the most active gases known to chemists. The air exhaled contains about the same amount of nitrogen as that inhaled, but it contains much less of oxygen, the latter having been replaced by an almost equal quantity of carbon dioxide.

Composition of the air. — One hundred parts of pure air contain about 20 parts of oxygen, nearly 80 parts of nitrogen (and other gases), and .04 of a part of carbon dioxide. Air coming from the lungs contains 16 parts of oxygen, nearly 80 parts of nitrogen, and over 4 parts of carbon dioxide. The air while in the lungs has lost 4 parts of its oxygen, there has been no essential change in the quantity of nitrogen, and it has gained 4 parts of carbon dioxide. The oxygen is in the air in order to supply an element to animals essential to their activity. The nitrogen in the air is not used in the body. The small amount of carbon dioxide in the air supplies the plants with carbon. Its quantity is being constantly added to by fires and by the breath of animals. The leaves of plants, aided by the sunlight, are constantly removing it, so that it is kept at .04 of one per cent in the air.

Foul and fresh air. — It has been believed for many years that the cause of bad air was the presence of carbon dioxide coming from the lungs. At one time it was supposed that the air of crowded rooms contained an unknown poison.

To-day, because of many studies, it is known that the carbon dioxide plays a very small part in contaminating the air of rooms and most of the foulness of air is due to a high temperature,* high humidity,* and lack of air motion. Fresh air means, therefore, not more oxygen or more "ozone," but air of low temperature, low humidity, and in motion. Eastman and Lee have shown that the pulse rate will increase from 67 to 106 as the temperature of the air rises from 74 to 110 F. and the humidity from 68 to 90. People must recognize these facts and adopt their way of living to conform to the knowledge we have. As a rule, the house is overheated, and in steam-heated rooms the humidity is too high. It is to be remembered that hot, humid, still air is to be avoided. The windows in the room should always be open sufficient to allow the air of the room to keep in gentle but continuous motion, the humidity to remain like that of the air out of doors and the temperature not above 68° F.

The hygiene of respiration. — Statistics* indicate that among civilized races a large proportion of the deaths is due to lung diseases. This proportion is frequently estimated as high as one seventh of the entire number. For this reason, it is important to care intelligently for the respiratory system.

The cilia of the air passages stop most of the dust before it reaches the lungs, but not all. If the dust is excessive, millions of particles enter the lungs. If a housekeeper would examine the air of the room with a beam of light reflected by a mirror during the time of sweeping, she would often be horrified, and would heed the caution of those who say that every door and window should be opened before beginning to sweep, and allowed to stay open for two hours afterward. If there is a breeze, so much the better; it blows the dust out, especially if she sweeps in the direction of the breeze. It is the presence of dust floating in the air, more than fragments of trash upon the floor, that makes a dirty home.

When the carpet is swept, dust comes from the carpet itself, especially if it is old. Curtains and hangings also hold dust. Hardwood floors, with rugs instead of carpets are recommended, and oilcloth and linoleum are also excellent substitutes for carpets. Rugs can be conveniently cleaned at any time, and the floor can be cleansed with a moist cloth.

Breathing through the nose. — (1) On account of the projections of the turbinate* bones and processes into each nasal passage and the roundabout way the air takes in passing through the nose instead of the mouth, nasal breathing brings the air in contact with a much larger extent of moist and warm mucous membrane than does mouth breathing. The air becomes warm and does not, like cold air, irritate the trachea and bronchial tubes. (2) The air becomes purified, because the hairs just within the nostrils and the mucous lining of the latter serve to catch particles of dust. (3) While a mouth breather is eating, sufficient time is not taken for chewing the food, but it is swallowed too soon, so urgent is the necessity for breathing. (4) In the habitual mouth breather, the nasal mucous membrane, from lack of stimulus of the cold air, dries and shrinks, causing discomfort; and since, in its dry condition, the circulation easily becomes obstructed, there is a predisposition to congestion and catarrhal nasal affections and injury to hearing. (5) An unpleasant expression of the face results from mouth breathing (Fig. 78). The lower jaw recedes, the upper teeth project, the nostrils are not developed and in a grown man may be no larger than during childhood. (6) A person has greater endurance in muscular exertion if he breathes strictly through the nose. He can hold out much longer, his lungs are kept more expanded, and the heart is not oppressed; and, after a while, a "second wind" comes to him, — for instance, during running. (7) The voice has more resonance if the nasal passages are open.

A Scotch physician, fully appreciating the importance of

proper breathing, has written a valuable medical paper, entitled, "Shut Your Mouth and Save Your Life." Sometimes the cause of stopping up the nose in children is enlargement through growth of glandlike structures in the upper part of the pharynx, called adenoids. They are just behind the posterior openings of the nasal passages, and can be easily removed if they become enlarged. Persons who sleep with the mouth open are likely to snore, and to awake in the morning with the mouth and throat dry.

Muscular action in breathing. — Expand your lungs, and see whether they will contract of themselves. Contract your lungs and see whether they will expand of themselves. See whether you can make waist, chest, and abdomen expand at the same time. You learned that the periods of rest taken by the heart muscles amount to how many hours daily? The breathing muscles also rest a considerable portion of the time; with calm and happy people they rest more than with people of anxious, unquiet dispositions. We can breathe by means of the expiratory muscles alone or by means of the inspiratory muscles alone, or by using each set alternately. When all the breathing muscles are relaxed, the lungs are at rest in what may be called the neutral position, since there is neither voluntary contraction nor expansion. In this position they are of about average size. If now we use the expiratory muscles and contract the lungs, the muscles may relax during inspiration which follows, for it will be accomplished by the elasticity of the abdominal walls and organs, and of the cartilages of the thoracic cage; for these were bent when the cage was pulled from the neutral position. Try this method of breathing for a few minutes.

Or, on the other hand, when the lungs are at rest, we may breathe by using the inspiratory muscles (Fig. 160) (diaphragm and intercostals), thus expanding the lungs from the neutral position, and allowing the muscles to rest, while the

elasticity of the parts forces out the air. Try breathing in this way.

This expanded breathing has the advantage, over contracted breathing, of removing pressure from the heart and large blood vessels in the chest, and allowing the heart to work with greater freedom. It also keeps the lungs more expanded. You learned in another paragraph that it is the usual method of quiet breathing; but strong, contracted breathing sends out fouler air from deep in the lungs.

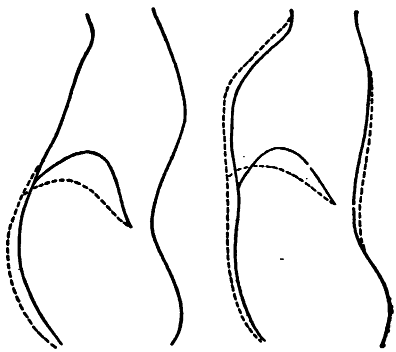


FIG. 159. FIG. 160.

Diagrams illustrating improper and proper methods of breathing. Dotted lines show area of expansion.

FIG. 159. — Here, owing to faulty posture, expansion of chest is impeded and breath is taken by the "diaphragmatic method."

FIG. 160. — Figure properly poised and free from constriction. Here the entire thorax can move freely, and natural breathing is the result.

In both of these ways of using the breathing muscles, there is a pause in the neutral position before the next breath. But in a time of great exertion, as when running, or during a time of excitement and in some forms of illness, there is no pause between breaths, and we use what may be called forced breathing.

Respiratory exercises. — It has been stated that strong contracted breathing sends out foul air from deep in the lungs. Some people argue from this fact that we can remove the waste material by deep breathing, and some even go so far as to say that by breathing exercises we can get strong and vigorous. *Now our physiology must help us at times when methods of getting health are proposed.* It is known in the first place that the body does not store up oxygen in

the body but takes in oxygen only in response to the needs of the body. If one stands at the window and breathes for 15 minutes will more oxygen be taken into the body? We have learned also that the rate and depth of respiration are governed by the amount of carbon dioxide in the blood, and when this gas is increased the respiration is increased in order to remove the waste. If we desire the effect of breathing exercises, we should engage in some game or activity that will make us breathe much faster. In this way our respirations will increase without our thinking about them, and in addition we will get the other desirable results of the activity.

There are some people whose chests are so small that they are unable to engage in any vigorous sport because their lungs are not developed enough to supply the required oxygen. Such persons need breathing exercises to increase the mobility* of the chest but in addition they need forms of activity like games, also running in the case of boys, and skipping in the case of girls. The improper ways of breathing that are seen are due to faulty methods of dress, and if these are corrected a great improvement will be noticed.

Abdominal Breathing, Chest Breathing, and Natural Breathing. — It should be remembered that breathing is a natural process. It is not necessary to teach animals to breathe. A race horse, needing a very efficient respiratory mechanism, breathes without being taught. The breathing process is natural in man. It is true that he may breathe with difficulty because of constricting clothing or poor posture, but *the correction of the conditions causing the defect should be made* rather than an attempt to teach some fancy method of breathing.

There has been much discussion among physicians, voice trainers, and elocutionists as to the proper way to breathe, some advocating chest breathing, and some advocating abdominal or diaphragmatic breathing (Fig. 159). The fact

that so elementary a process as breathing is still a subject of discussion illustrates how imperfect is the state of our physiological knowledge, especially when an attempt is made to apply it to practical purposes. The author believes that pure chest breathing and diaphragmatic breathing are both wrong, and that what may be termed natural breathing is the method to teach when corrections are to be made (Fig. 160).

Natural breathing employs movement of both chest and diaphragm, the greatest expansion being in neither chest nor abdomen, but at the waist (Fig. 161), and diminishing in amount both upward and downward. The objection to pure chest breathing is that the marked movement of the upper part of the bony cage requires exhausting effort; such movement can be employed without waste of strength for only a short period, as in gasping for breath or during great muscular exertion.

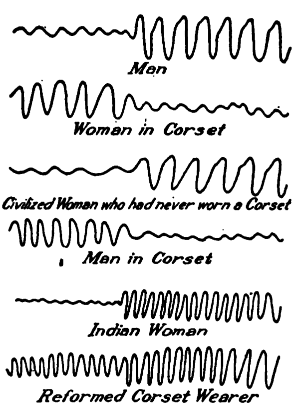


FIG. 161. — Breathing tracings (Kellogg). Motion of chest recorded at left and of waist at right. Interpret these tracings by what is shown in Fig. 160.

In natural breathing, the diaphragm contracts but at the same time the ribs are lifted upward and outward, and the points of attachment of the diaphragm are thus raised and separated so that the diaphragm flattens without any great descent. But in pure abdominal breathing, the movement is confined to the diaphragm and abdomen, and lateral action of the chest is suppressed (Fig. 159). The effect of this is to cause too great a displacement downward of the liver, stomach, kidneys, colon, and other organs. But in natural breathing, any great degree of downward movement

is prevented by expansion of the trunk at the waist. In abdominal breathing, the abdominal walls are entirely relaxed as the diaphragm descends, and the liver and other organs are moved but not compressed. In natural breathing they are compressed and slightly moved, and the compression squeezes the blood out of them toward the heart and presses the lymph upward, through the thoracic duct; the expansion of the chest at the same time helps to draw the blood upward. During expiration fresh blood is sent back to the abdominal organs, and so they are kept fresh and strong. Women who wear skirts with bands tight enough to support them at the waist, gradually lose the power of lifting the ribs outward at the waist. This expansion is most important for good breathing, because the lungs are largest there. The belt used by men for supporting the trousers, should rest on the hip bones (ilium) and not above them.

*Ventilation.** — The evil effects of rebreathing air can hardly be exaggerated. The blood stagnates, the heart acts slowly, the brain is clogged, the head aches, and either a dull or a feverish feeling arises. The body becomes sensitive to cold. The skin becomes pale, the blood is loaded with impurities, and the whole body is obstructed with refuse material. In such a human body, colds, catarrh, consumption, and other diseases readily develop. The constant breathing of even the slightly impure air of most private houses cannot but tend to undermine the health and prevent that perfect soundness of body which thorough ventilation or life in the open air insures.

Judgment with regard to ventilation is rare. In many churches and assembly rooms the windows are tightly closed except in warm weather. If, during the meeting, the room becomes too warm, some one will open one or more windows to their full height; the strong draught soon cools the room and chills some one, whereupon he goes to the window and

shuts it tight. One absurd extreme thus follows another. All that was necessary, if there was no scientific provision for ventilation, was for all of the windows to have been opened, for an inch or less, when the assembly began, and allowed to remain so; then no one would have been too hot or too cold, or would have suffered from vitiated* air.

The ventilation of the schoolroom is often deplorable. A visitor, upon entering a schoolroom, especially if the school has been in session for an hour or more, may notice a stifling, foul-smelling atmosphere. The children have rushed in from their active games with their clothing saturated with perspiration. Their healthy skins perspire more freely than do those of adults. Some of them may have coughs or colds, some may have come from sick rooms. The dust from the pattering of many feet, the clouds of chalk dust, accumulate until they become almost unbearable, and all that gets out leaves the room on the clothes of the pupils, or on the mucous membrane of their nasal passages and lungs; for the janitor is more ignorant usually than the housekeeper, and unless forced to do so he will not open the windows before sweeping because of the trouble; or, if persuaded to open them, he must be compelled by the principal to allow them to remain open for the dust to blow out, otherwise he will close them on leaving each room to avoid the annoyance of returning.

These are the conditions of many, many schoolrooms and homes, for, unfortunately, some persons' knowledge of physiology is never put into practice. It is not strange that lung troubles are common and that people, ignorant of their cause, take "patent medicines" instead of pure air. Many of the Indians of Patagonia died of consumption within nine months after being taught by the missionaries to live in houses. The missionaries neglected to tell them *how* to live in houses.

It is necessary to give children knowledge of the geography

of Africa and other remote lands, but it is at least as necessary to train them to sit and to stand correctly. Frequent periods of relaxation and play would help to counteract the deforming effects of prolonged sitting, would help them to grow up well-formed men and women, and would make them more ready to learn the geography as well.

The health of children at school often suffers, and parents usually think it is because of the number of studies. This

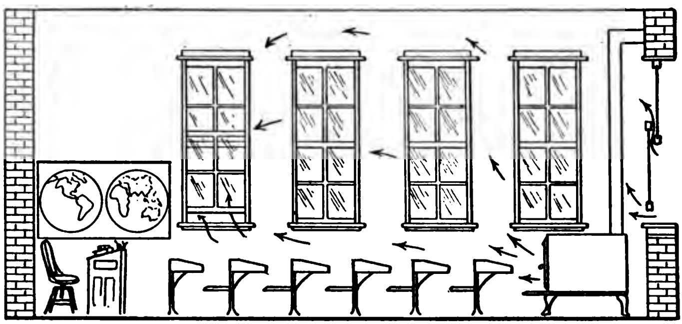


FIG. 162. — The proper method of ventilating a room with stove. The stove is on the side toward the cold winds. The inlet is near the stove, the outlet farther away. If the window near the stove were lowered from the top, what would happen? If another window near the stove were opened, what might happen? If the prevailing cold winds came from the opposite direction, what changes should be made in the room? How do you ascertain whether the outlet fails to serve its purpose and become an inlet?

idea is no doubt largely erroneous. The breathing of the bad air, both at home and at school, the close confinement in the schoolroom, sitting in a cramped position, and studying by improper light, are the true causes in a majority of cases.

Some persons in their anxiety for pure air become extremists, and forget that the body may likewise be injured by cold. In ventilating a room, not one but two purposes must be kept in view: to furnish air that is pure, and air at the proper temperature.

Methods of ventilation depend upon the principle that hot air is lighter than cold air and is pushed up by it. If you have two openings for ventilation, one higher than the other, at which opening does the warm air go out? If the higher opening is near the ceiling, do the persons in the room get the coldest or warmest air? Does such a method economize the fuel? If the inlet is near the floor, why should the stove be near the inlet? Why should the outlet be on the side of the room farthest from the stove?

Fig. 163. — Window board prevents cold air blowing on those near the window. The air is directed upward.

Good ventilation is arranged so that the fresh air shall be heated before or just after it enters the room, and that it shall pass across the room in order that the inmates may get the benefit of both its warmth and its purity before it passes out (Figs. 162, 164). Test the direction of the air currents in your bedroom and in your schoolroom by means of a spider web hanging from the end of a stick. Why is it best not to have the outlet on the side of the house toward the prevailing wind in winter? If the inlet is so situated that the cold air does not pass over the stove, a board or screen may be placed before the window to deflect the current upward and prevent its chilling those seated nearest the window (Fig. 163). If you find by holding your hand near the inlet that there is a good inward current, you may be sure there is sufficient outlet; although if it is not far enough from the stove, heat will be wasted. If you know there is a strong outward current, for instance when a fire is burning in an open fireplace, you may be sure that the same amount of air is entering somewhere, if only through minute cracks.

When over-enthusiastic people become interested in ven-

tilation, they sometimes injure themselves by chilling draughts and low temperatures. The temperature of the room should be kept between 65 and 68 degrees F. The foregoing directions for ventilation apply to cold weather. For warm weather no special directions are necessary, for most people are more anxious to avoid unpleasant heat or the possibility of soiling their collars with perspiration, than they are moved by the danger of breathing foul air.

The effect of tobacco on the respiratory organs. — The hot smoke irritates and dries the mucous membrane of the mouth and throat, producing an unnatural thirst that may readily lead to the use of alcoholic drinks. Inhaling the poisonous smoke, which occurs to the greatest degree in cigarette smoking, inflames the delicate mucous lining of the bronchial tubes and air cells. There may result from this an irritating cough, short breath, and chronic bronchial catarrh.

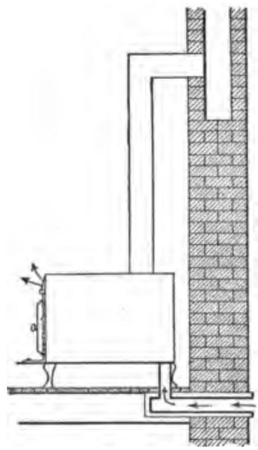


Fig. 164. — Stove for rural school where furnace is not used. The air enters through a special inlet and is warmed as it passes through a hood surrounding the stove.

General considerations. — The hygiene of respiration is only a phase of the hygiene of living. *All the methods that are available to help people to live finer individual lives and to preserve their strength and health for the welfare of the race are valuable.* Cleanliness of air is very important, but cleanliness of living is more important.

Cleanliness. — Nearly all people are very careful to wear clothes that are perfectly neat and clean. Dust or mud upon their clothes is considered the highest degree of uncleanliness. Many think it of the highest importance to health and refinement to keep the skin clean by regular baths.

But there are a few that think it of still greater importance to keep the air clean that goes into the lungs. A few also think it necessary to keep the alimentary canal pure throughout by reasonable eating and living. We also meet with those who believe not only that the *clothes*, the *skin*, the *lungs*, the *digestive organs*, must be kept clean, but that the *blood* must be clean and fresh, ever renewed by a strong and vigorous flow, and they so live that as far as possible it shall always be so. The daintily dressed lady or the dandified man would be horrified at a particle of mud that fell upon the clothes, but sometimes if you are so unfortunate as to catch a whiff of the breath of such a person, its repulsive, sickening odor shows that foulness and uncleanliness have taken possession of the lungs, or digestion, or blood. We should be careful to observe these five degrees of cleanliness, but which should we value most highly? There is another aspect of cleanliness that relates to the way the person lives. It is concerned with thoughts and actions. What is the relative value of these three: clean clothes, clean body, and clean conscience?

The Mistake of the Over-studious. — The pale student, thinking only of the desire for learning aroused by teacher or parents, and neglecting the promptings of his natural instincts* toward complete living, thinks he is doing wisely and right when he is constantly delving into books. On the contrary, he is sinning against part of his nature and unfitting himself for accomplishing the best work he is capable of doing.

The Essential Unity of Body and Mind. — All students should remember the fact that the individual, particularly as regards mind and body, is a unit and the health of the whole is dependent upon the health and vigor of its parts. The mind cannot achieve extraordinary success at the expense of the body, without a loss of real health values in both mind and body. Furthermore, it is important to remember that

the brain, in its development from lower forms, followed the development of the muscular system, and for this reason we must always look to the muscular system as the foundation upon which to build a safe and serene mind. This does not mean that one should seek to develop large and unsightly muscles with the hope of thereby achieving mental power, but it does mean that *bodily activity in physical forms is absolutely essential for the highest and finest development of the brain and nervous system.* The student in school or college who seeks to be excused from physical education classes is progressing in a direction which will bring a weak and devitalized body unless he provides on the outside a large and wholesome participation in games or sports. In this day of interest in and plans for national preparedness, it is the duty of the boys and girls of the nation to share in this movement and bring to the service of the nation in all fields of endeavor a finer body and a more vigorous spirit.

APPLIED PHYSIOLOGY

Exercise I

1. State how in the case of a person of poor figure, a gradual remolding of the cartilages, the strengthening of the muscles, and the practice of chest lifting may each contribute toward acquiring a correct and perfect figure.

2. How far is it in one's power to determine the shape and appearance of his own body?

3. Give reasons why the weight of our clothing should hang from the shoulders and not from the waist.

4. How can the hat be ventilated? (A punch for making the hole costs a dime.)

5. Name habits that impair the power of the lungs.

6. How could you convince a person that a bedroom should be open while and after it is swept? That it should be ventilated at night?

7. Why do some persons "get out of breath" readily after a meal?

8. Can a person become so used to bad air that he will not notice it? That it will not injure him?

Exercise II

9. Which is the more offensive, the tobacco chewer, who chiefly pollutes the ground, or the smoker, who pollutes the air?
10. Why are those who have pimples on the face likely to multiply their number by picking and squeezing them with the fingers?
11. Give the advantages of slow, deep breathing as compared with quick, shallow breathing.
12. Why do those who stand up to hoe not get tired half as quickly as those who bend or " hump " over?
13. Why do students who sit in rocking-chairs, or from other causes lean the head forward when they study, often find that they recover from drowsiness if they sit erect?
14. How are high collars a fruitful source of bad colds?
15. Is ventilation easier in winter or in summer?
16. If the draught up the chimney of the fireplace, when the fire is burning, takes up a volume of air sufficient for many people, why is it unwise to open a window?

LABORATORY EXERCISES

Experiment 1. To study modifications of the breath.

Study the following list of experiments with your own breathing. Write after each word I or E according as inspiration or expiration is chiefly involved in the action:

Sighing	Coughing	Sneezing
Sobbing	Laughing	Hiccoughing
Crying	Yawning	Snoring

Experiment 2. To study the mechanism of respiration.

Material. — Respiration apparatus as show in Figure 165.

Method and observation. — (*a*) Locate upon the respiration scheme what corresponds to the following structures: 1 trachea, 2 glottis, 3 thoracic cavity, 4 lungs, 5 intrapleural space, 6 diaphragm. (*b*) Produce inspiration by lowering the diaphragm. What happens to the lungs? What change occurs in the pressures in the chest cavity? (*c*) Produce expiration by raising the diaphragm. Describe and explain what is noticed. (*d*) Close the glottis and try experiments *a*, *b*, and *c*.

Experiment 3. To study the effect of forced breathing.

Material. — Watch with second hand.

Method and observation. — The subject, seated, breathes naturally and counts the rate. Then breathes as deeply as possible about 18 times a minute. The attention should be fixed on drawing deep inspirations. Continue it for 30 seconds, at once at the end of the 30 seconds count the rate and compare this with the rate before the experiment.

The deep inspirations removed the excess of carbon dioxide from the blood, and with this removed the stimulus was less to the respiratory center in the medulla and so the rate was slowed.

Repeat the experiment for one minute.

Experiment 4. To study forced breathing without the excessive elimination of carbon dioxide.

Repeat experiment 3 while holding a paper bag over the nose and mouth of the subject. Record the results obtained, compare with experiment 3 and explain.

Experiment 5. To study the production of apnea (period of no respiration).

(*a*) At the end of a normal expiration, the subject holds the breath until no longer able to do so. How long can it be held?

(*b*) Repeat experiment (*a*) after taking a deep inspiration and counting from the end of a normal expiration. How long can it be held? Is this period longer or shorter? Why is this so?

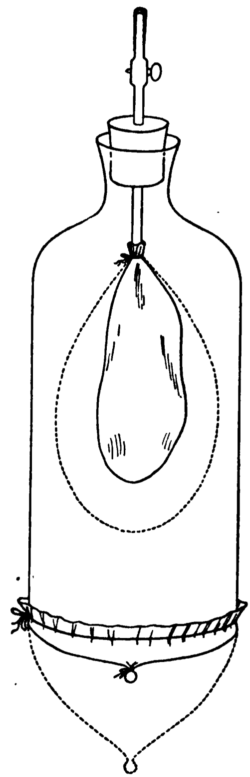


FIG. 165. — This apparatus is made by tying over the bottom of the bell jar a sheet of dental dam which has tied in the center a marble for a handle. The mouth is fitted with a cork through which passes a glass tube with stop cock. At one end of the glass tube is tied a small rubber bag. When the tube is inserted in the jar and the cork put in place the rubber diaphragm should be pressed upward as it is in the human body.

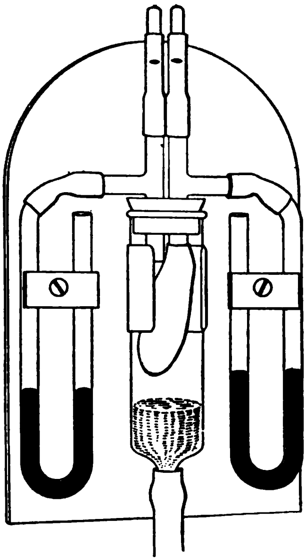


FIG. 166. — The respiration scheme. About one third the actual size. (Harvard Apparatus Co., Boston.) The water diaphragm is made to move up and down and causes a filling of the rubber bag. The water is moved by means of water in connection with the tube at the bottom of the picture. The left-hand mercury U-tube shows the change of pressure within the interpleural space; the other U-tube shows the change in pressure within the lung.

Experiment 6. Respiration may be studied by means of the apparatus shown in Figure 166 obtained from the Harvard Apparatus Company, Back Bay Post Office, Boston, Massachusetts.

GLOSSARY

Atmosphere. — The gaseous mass, chiefly air, that surrounds the earth. This mass at sea level will support a column of mercury 30 inches high at a temperature of 0° C. This pressure is sometimes stated as being equal to 15 pounds to the square inch.

Humidity. — Refers to the moisture in the atmosphere. This moisture varies and two terms are used to express the relation as it exists at different times.

Absolute humidity. — The amount of water vapor in the air expressed in the number of grains of moisture per cubic foot of air.

Relative humidity. — The ratio of the actual quantity of moisture in the air to the quantity that would saturate it at the temperature and pressure of the air at that time.

Insertion. — The point or points of attachment of a muscle to a bone. The insertion, as contrasted with the origin, the other attachment, is considered as more movable. Another distinction between insertion and origin is that the latter is on the bone nearer the center of the body, and the insertion further from the central part of the body.

Instinct. — A natural, spontaneous impulse moving to action without the intervention of reason. This impulse acts most powerfully in connection with preservation and development.

Mobility. — The quality of being freely movable.

Negative pressure. — The pressure of the atmosphere in millimeters of mercury is 760. A pressure less than 760 mm. of mercury is a negative pressure.

Origin. — One of the points of attachment of a muscle to a bone. It is attached at the more stationary part of the bone or is nearer the central part of the body.

Statistics. — A mass of facts pertaining to a body of things, systematically gathered, classified, and tabulated. Statistics are essential in the conduct of a large business, in manufacturing and in all scientific studies.

Temperature. — The condition of the body or thing as regards heat and cold.

Turbinate. — Top-shaped. The turbinate bones of the nose are of this shape.

Ventilation. — The process of providing free circulation of air.

Vitiated. — Refers to air. To vitiate is to injure the qualities. Vitiated air is air that has lost the qualities of freshness, of freedom from dust and bacteria, and is not of the proper temperature and moisture.

CHAPTER XV

THE NERVOUS SYSTEM

I. The Functions of the Nervous System.
  - Communication
  - Coördination

II. The Nerve Cell the Unit of the Nervous System.
  - Dendrites
  - Axone
  - Neuron
  - Ganglion
  - Nerve center
  - Neuroglia
  - Terminations of nerve fibers
  - Efferent, afferent, and association fibers

III. Nerve Action.

IV. Sensations.
  - General
  - Special

V. Injury to Nerves.

VI. General Arrangement of the Nervous System.
  - The spinal cord
  - The autonomic system
  - The brain

The functions of the nervous system. *Communication.* — The amœba and other one-celled animals need no nervous system, but the larger animals, consisting of a colony of cells, as it were, need a means of communication between the cells, in order that their life may be harmonious. On Robinson Crusoe's island a telephone or a post office system would have been of no use, but a number of individuals living together and practicing a division of the labor of the

community for their mutual advantage, are compelled to communicate with each other in order to make their wants known. The lowest of the many-celled animals, such as the sponges, have no cells specially set apart for carrying messages between the cells, but each cell passes the impulses it receives to its neighbor cell. This will do for a small and simple community of cells, but a larger community, like one of the higher animals, possesses certain cells, called nerve cells, whose chief function is to keep up the communication between the cells. In the chapter on nerve tissue you learned that the nerve cells did this by means of branches, which in some cases are several feet long.

Coördination. — Did you ever see a crowd of people at a fire when a neighbor's house was burning? Everybody ran out, yet very little was done. Everybody shouted orders which nobody obeyed. But on the arrival of the chief of the fire department or the head of a fire company, who had had experience in the control of men fighting a fire, the scene changed; valuable property was saved, and the fire was stopped.

Every community has certain deliberative and controlling bodies; these may be a board of aldermen, a court of justice, a legislature, or a congress. In a similar way the great number of individual cells which make up the human body must be controlled by some central power, or they will not work in harmony; nothing will be accomplished, but a state of anarchy and helplessness called disease will follow. The seat of this central controlling power is located in the brain.

The nerve cells receive, modify, and send out impulses. By these three kinds of acts the nervous system accomplishes what is called coördination. This term signifies not only that the cells work together at the same time, but that they work together as a part of a plan for the accomplishment of some definite result. Suppose that a man sees a bright

dollar on the road and picks it up. In order that he may do this, the cells receiving through the optic nerve the impression of the shining coin must be in communication, either directly or indirectly, with the muscles of the hand; and that the hand may reach the coin, the muscles of the arms, legs, trunk, head, and neck must act together. Even the heart and respiratory muscles must modify their action somewhat to suit the movement.

Other Organs besides Muscles Must Be Coördinated. — Suppose a boy sees a large red apple. He notices the odor which tells him it is ripe, and his "mouth waters" for it; that is, the salivary glands begin to work, even before he puts the apple to his mouth. The chewing and swallowing, the secretion and peristalsis in the digestive organs, are all carried on under the control of impulses that reach them through the nerves. Without these impulses, the salivary glands would not work when the mouth was chewing the food; the dry food would stick to the esophagus and have to be washed down with water; the gastric juice would not be secreted at just the right time; the food would ferment in the stomach, and the person would soon be ill.

The nerve cell the unit of the nervous system. — You learned when studying the tissues that the nervous system consists of nerve cells with their branches, called nerve fibers. Nerve cells are microscopic bits of protoplasm, like other cells, yet they are remarkable among animal cells for their large size. Some of the cell bodies in the spinal cord are so large as to be almost visible to the unaided eye, and they have branches leading from the cord to the hand or foot. Each cell contains a nucleus, within which is a nucleolus (Fig. 167). Nerve cells are the most remarkable in the body for irregularity of shape (Fig. 176); some of them have so many branches that they have a starlike appearance.

*Dendrites.** — The dendrites are branches of nerve tissue from the cell body. The dendrites of a nerve cell are the

treelike branches which bring impulses to the cell (Fig. 31). Through the dendrites the cell may be in communication with numerous other cells. A branch of one cell does not join the branch of another cell. It has not yet been settled by physiologists whether the ends of the dendrites of communicating cells actually touch.

The axone and its parts. — In most of the fully developed nerve cells, one of the branches is very greatly prolonged as a fine thread of protoplasm, which becomes the core of a nerve fiber (Fig. 167). Every nerve fiber has such a core.

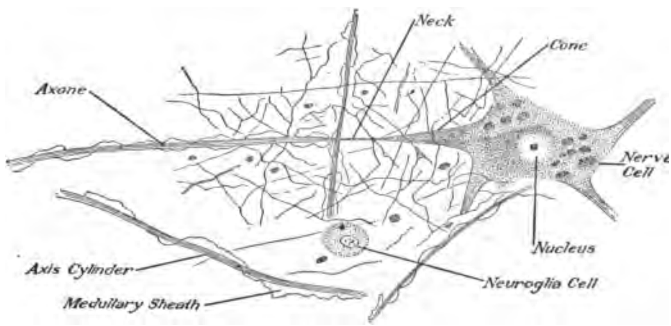


FIG. 167. — Nerve cell showing axone, medullary sheath, and field of fibers.

In most of them this central thread of protoplasm becomes covered with two coats (Fig. 32); an outside protective coat forms a tube, called the connective sheath, and between the walls of this tube and the central thread is a coat of semiliquid, fatty substance called the medullary sheath, which, shining through this outer sheath, gives a silvery white appearance to the fiber. Such fibers are called medullated* fibers, or white fibers. Some fibers lack the medullary sheath, and are called non-medullated, or gray fibers.

*Neuron.** — One nerve cell together with all its branches, both dendrites and axone, is called a neuron. A neuron is the unit, and the nervous system is built up of an enormous

number of these units, together with supporting tissue (Fig. 167).

Many nerve fibers may be bound together by connective tissue until they form a cord large enough to be seen by the unaided eye (Fig. 168). A bundle of nerve fibers is called a nerve. The sciatic nerve in the thigh is as large as the end of the little finger. The fatty sheaths of the fibers are supposed to insulate the fibers so that a nerve impulse cannot go across to another fiber; they serve the same purpose as the insulating substances with which wires used to conduct electricity are sometimes coated. As a rule, a large nerve accompanies an artery down the inside of each limb, and across the joint on the side toward which the limb bends. Thus they are well protected. One exception to this is a nerve cord which crosses the elbow on the side away from which the elbow bends. Therefore, it is sometimes hit, and the end of the bone there is called the funny bone because of the tingling sometimes felt, as if it were in the hand at the termination of the nerve.

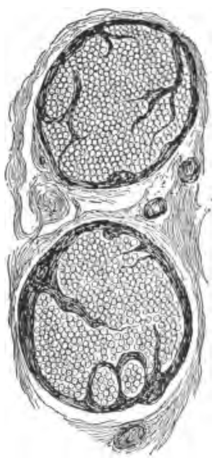


FIG. 168. — Section of two nerves, showing many nerve fibers bound together in connective tissue sheaths, to make nerves.

Ganglion. — The cells are not scattered singly throughout the nervous system but are gathered into groups. This seems to afford easier communication from one cell to another through their branched dendrites, which are unusually short. One such group of cells situated outside the cord is called a ganglion. Ganglion is not to be confused with the term "nerve center," which relates primarily to function. The term ganglion refers to structure.

Nerve center. — A group of nerve cells, situated in the

brain or spinal cord, performing a definite function, such as controlling the muscles of breathing, form what is called a nerve center. The brain consists of a number of large nerve centers with their connecting fibers. There are many nerve centers in the spinal cord also. Where nerve cells, ganglia and gray fibers are abundant, the nerve substance is gray; where medullated fibers with their hidden gray cores are abundant, the nerve substance is white in appearance. This led anatomists and physiologists in times past to classify nerve substance as gray matter and white matter.

Neuroglia. — The fibers and cells of both the gray and the white matter are held in place by a tissue called neuroglia, which is composed of extremely fine fibers and minute cells. Though like connective tissue in function, its chemical composition is different; nor is neuroglia developed from connective tissue (Fig. 167).

Terminations of nerve fibers. — If we could trace toward the central nervous system the course of the various nerve fibers in a nerve like the great sciatic, for example, we should find that every one of its thousands of nerve fibers ends, without exception, in a nerve cell in the spinal cord or brain, or in any one of the ganglia near the central nervous system. If we should trace these same fibers away from the central nervous system, they would be found to have various endings. Some enter the muscles where they subdivide, and finally end in the muscle cells. Others follow the blood vessels and end in the muscle fibers forming the middle layer of their walls. Others go to the gland cells; for example, the sweat glands in the skin. Others, passing to the skin, terminate at the roots of the hair, or in curious little bodies composed of cells and called touch corpuscles (Figs. 169, 170). Depending upon its function every nerve fiber ends centrally in a nerve cell or peripherally* in either a muscle cell, a gland cell, or a sense organ cell. Fibers that end centrally are sensory and carry impulses to the brain or cord;

fibers that end peripherally are motor or secretory and carry impulses from the brain or cord.

Efferent, afferent,* and association* fibers.* — Fibers that connect nerve cells with muscles or glands are called efferent (*outward bearing*) fibers; (they may be motor or secretory); those that connect nerve cells with sense organs are called afferent (*in bearing*) fibers (they are always sensory). There is a third kind, which connects nerve cell with nerve cell in the brain; they are known as association fibers.

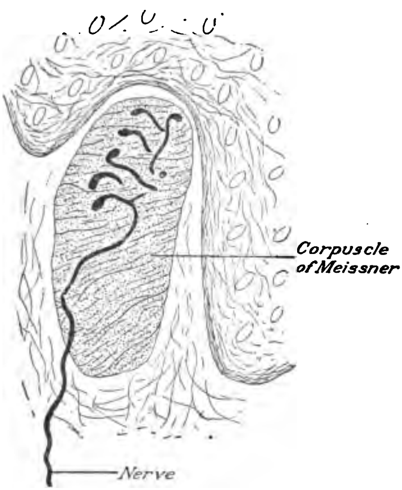


FIG. 169. — Sensory nerve ending in skin, showing tactile corpuscle of Meissner.

Nerve action. — If an afferent nerve be irritated at its outer endings in the cells of the tissues, an impulse will travel to the brain or spinal cord. If it goes to the brain, consciousness of the impulse will be apparent; if it goes only as far as the cord, there will be no real consciousness of the fact. In either case there may be a motor response to the sensory impulse in the form of a reflex* act. Impulses may originate in the brain and pass to different cells in the body, causing them to act. This occurs when one consciously makes a muscular movement. Transmitting nerve impulses is the whole duty of nerve fibers. The endings of the nerves are so abundant in the skin just beneath the epithelium that the point of a needle cannot enter without causing pain. They are more numerous there than in any other part of the body. Afferent nerves are not so abundant in the muscles

and internal organs as in the skin, so that a cut gives most pain as it enters the skin and may be continued into deeper parts with only slight pain. Efferent nerves begin in the nerve cells of the spinal cord and end in the muscles and glands of the body. Efferent nerves and efferent impulses have three functions, — controlling motion, secretion, and growth. Because of this multiplicity of function, it is desirable to call them efferent nerves rather than to use the old term "motor." The nerve impulse, as demonstrated in the frog, travels about 100 feet per second. This is the speed of an express train going 70 miles an hour. It is probable that in warm-blooded animals, such as man, the rate is even faster.

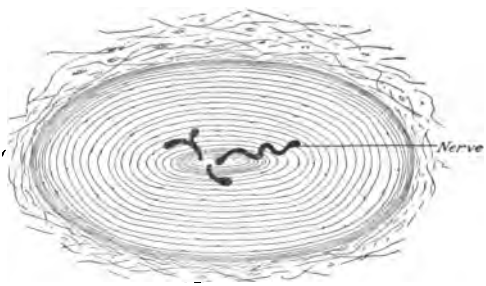


Fig. 170. — Pacinian body. These touch endings give the sense of pressure. Located in the dermis.

General sensations. — The cells of the body are constantly sending impulses to the central nervous system, signifying their needs. These impulses give rise to feelings to which the mind assigns no definite location in the body; hence they are called general sensations. Such feelings as hunger, thirst, fatigue, and sleepiness belong to this class. They are as well understood by a baby or any young animal as by a man, and unlike the special sensations, the meaning of general sensations does not have to be learned, as the memory of them owing to inherited habit seems to reside in the nervous system. General sensations are sometimes called instincts.

Special sensations. — When something outside of the body acts upon the nerves, it produces a feeling or sensation by

which the mind forms ideas of the surroundings of the body. The meanings of these feelings must be learned when first perceived, and they are mostly learned in childhood. The special senses, taste, sight, smell, pain, temperature, and muscular sense, are of such importance that all will be included in a separate chapter.

Injury to nerves. — If motor or efferent nerves going to a muscle are cut, there is paralysis of the muscle, so that there can be no voluntary or reflex action in the part. If an efferent nerve going to a gland is cut, the function of the gland will be almost suspended. Even if food is taken into the mouth and the sensory nerves carry the news to the brain, the efferent nerve being cut, no impulse can return and the secretion will be very slight. When the motor nerve to a part is cut, the cells will be almost too inactive to absorb and carry on growth and repair; hence unless continually under the influence of motor nerves the cells dwindle away. When the cells are much used, the impulses sent cause them to take in more nourishment and to grow in size. Thus a muscle increases in size and strength when much used. You learned that during the action of a muscle, the vasomotor nerves going to the arteries in the muscle cause what change? Will this also aid in growth? When a nerve is cut, the ends, if placed together, will grow again, the parts supplied by it being paralyzed in the meantime.

Nerves may become inflamed, and the disease is called neuritis, just as inflammation of the tonsils is called tonsillitis, or of the stomach is called gastritis. Neuritis of the sciatic nerve is called sciatica; it is a very painful disease. One of the many dangers of using alcohol is that it may produce neuritis. Either slow, steady drinking or occasional "sprees" may cause it. The disease gives no warning before it comes, and may remain a long while. Rheumatism or malaria may also cause it, but alcohol produces the disease as often as all other causes combined.

General arrangement of the nervous system. — The brain and the spinal cord make the central nervous system. The nerves coming from the brain are the cranial* nerves (Fig. 171). There are twelve pairs. The nerves from the

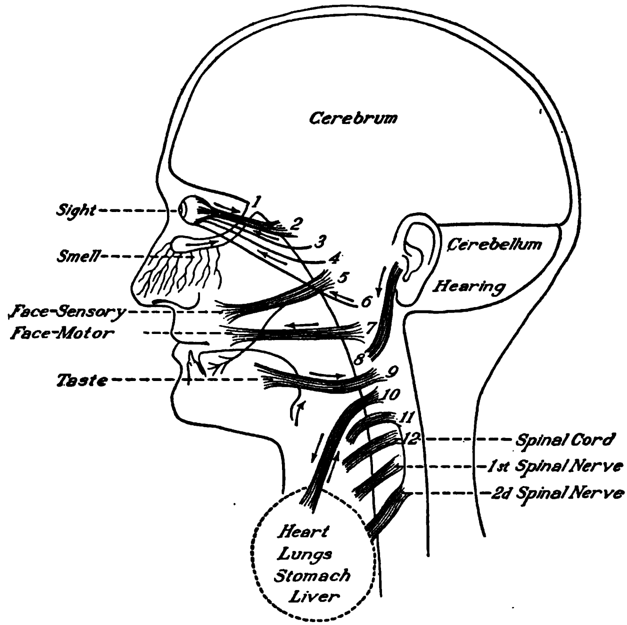


FIG. 171. — Diagram of the twelve cranial nerves. These are twelve pairs of cranial nerves which arise from the brain and go out through the holes in the lower wall of the skull. (How many pairs of spinal nerves are there?) The cranial nerves are numbered according to the location of their roots, from above downward.

cord are called the spinal nerves. There are thirty-one pairs of spinal nerves. These nerves running from the central nervous system make up the peripheral system. There are other nerves connecting mainly the involuntary structures with the cord. This connection is made by nerves that end in masses of nerve cells (ganglia) lying along each side of

the front of the vertebral column. These make up the autonomic* system.

The spinal cord. Structure. — The various white nerve fibers, both efferent and afferent, of the entire body unite and form forty-three pairs of larger nerves; twelve of these pairs, called cranial nerves, go to the brain, and thirty-one pairs, called spinal nerves, go to the spinal cord. Each one of the sixty-two spinal nerves enters the spinal cord by two roots, one posterior and one anterior. It is significant that all the efferent and afferent fibers of a spinal nerve separate from each other. The efferent fibers enter by the anterior root, and the afferent nerves by the posterior root (Fig. 173). The afferent fibers do not really enter the cord but end in a ganglion on the posterior root, and the ganglion sends dendrites into the cord by the posterior root. The spinal cord extends from the foramen magnum "or great opening," in the occipital bone down to about the second lumbar vertebra. What parts of a vertebra form the canal for the cord? Is the canal made of bone throughout its length? How are the vertebræ united with one another?

The spinal cord is about the size of the little finger. It is only about two thirds as large as its tube, so that it is not likely to be injured by bending the spinal column. The rest of the space in the canal is taken up by a lymphlike liquid, and three membranes called meninges which form a triple covering for the cord. These membranes extend into the skull and cover the brain. An inflammation of them constitutes a very serious disease called cerebro-spinal meningitis.

A cross section of the spinal cord shows that it is a double organ (Fig. 172), the halves being united by a narrow portion; it shows also that the central part of the cord is of gray matter in the outline of a butterfly, and surrounded by a thick layer of white fibers. The gray portion is made up of nerve cells that give off fibers, many of which go to the

spinal nerves and some go upward in the outer white portion of the cord. The white tract also contains motor threads

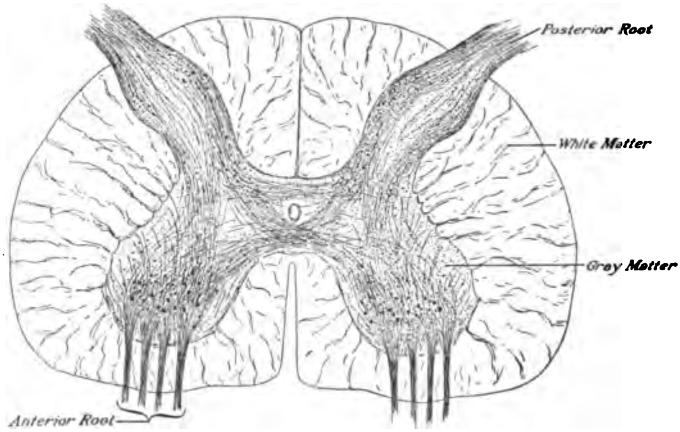


FIG. 172. — Cross section of the spinal cord. Afferent impulses come in over the posterior root; efferent impulses go out over the anterior root.

that bring impulses from the brain to the cells in the gray matter.

Function. — The brain sends impulses to the cells in the spinal cord, and they, being aroused, in turn send motor impulses to the muscles. When a person wills to move his hand, an impulse goes to the spinal cells, and they in turn send impulses that cause a contraction of the muscles in the arm. The brain sends about ten impulses per second to keep the muscle in action. Thus, before it can relax, another impulse reaches it. Each muscle has its own set of spinal cells in the cord which act as a relay station between the muscle and the brain. The cells of the spinal cord have another very important duty; they largely control reflex action. At times it would take too long for the brain to act, so the body needs a quicker governing power to supply its needs or protect it from injury. If the finger touches a hot object, the brain becomes conscious of the

burn and of the movement of the finger at about the same time. There are also many acts that are performed so often that the spinal cord acquires the habit of sending back the appropriate impulses. Thus muscles and other organs may be controlled and the brain be relieved to attend to other duties.

The same motor cells of the spinal cord that produce motion in a part, also exercise an oversight that controls the growth and nutrition of the cells in that part. The impulses from the spinal cells furnish a constant stimulus to growth and repair.

A crumb entering the larynx brings on a fit of coughing. A dash of cold water makes us hold our breath. A pinch of pepper causes us to sneeze. If the foot of a sleeping person is tickled, he will kick; if a fly settles on his face, he will brush it off. Sometimes a person in an unconscious condition will drink a cup of water if it is placed to the lips.

If the back is broken, reflex actions persist although all sensation and volition concerning the parts below the injury are suspended. The leg will kick when the foot is tickled, etc. A surgeon tickled the foot of a man whose spinal cord was injured, and the feet kept up a vigorous kicking. He asked the man if he felt it; he said, "No, but you see that my feet do." On carefully testing the sensibility of such a man, a line can be traced girdling the body, dividing the sensitive from the insensitive part. The brain also may act seemingly in a reflex manner as in cases of somnambulism, or sleep-walking.

When one is learning new movements, such as walking, skating, writing, riding a bicycle, each movement is a voluntary one as far as the will is capable of watching so many muscles. The movements are, therefore, slow and awkward. After the movements have been made many hundreds of times, they become easy and graceful, and also less voluntary. This is accomplished by the nerve impulse select-

ing the pathway that gives the right response. At first many pathways are used and tried. When the pathway is found that gives the result sought and there is pleasure in the reaction, then the movement is learned and it becomes easy and graceful.

We must not think of reflexes as being only related to muscles and movement. They may have a character that prevents or suppresses movement. A dash of cold water on the chest will inhibit respiration. A sudden emotional shock may be so terrifying as to prevent muscular contraction and one will stand still in the face of great danger. Reflex activity of glands is often not related to movement. The secretion of tears, caused by a cinder in the eye, is reflex. The impulse is carried to the lachrymal (tear) gland by the secretory nerves. These nerves are efferent but not motor.

Education of reflex action consists mainly of the formation of habits. The impression on the nervous system from the training is made chiefly on the spinal centers. When the muscles of the hand are educated, it is really the spinal cells that are educated. During youth, one is always acquiring good habits or bad habits. The habit of an upright, easy walk, the habit of dropping into a stooping posture, of putting the hands in the pockets, of making wry faces, of mumbling and stammering, or of talking distinctly and without hesitation, may be acquired, and will probably remain through life, for impressions made on the nervous system in youth are lasting. The habit of eating temperately of pure food, the habit of stuffing, of awaking the nerves with stimulating condiments, of using alcoholic stimulants, of using tobacco, are easily acquired, but are lost with difficulty. Good habits are good friends; bad habits are enemies. It often requires years of constant effort to root out bad habits, but it is very easy to keep them out in the first place. Yet if the wish and will for a better habit is really strong, one need never despair, for on account of the large size and great

activity of the brain, and its preponderance over the lower reflex centers, man is distinguished above all other animals by his power of forming new habits. If our ideals are high, we can go on forming better habits, and intrusting them to the keeping of the nerve centers, and thus make step after step toward our ideal. If our ideals are not high, or if they are mere theories and never affect our acts, we may never improve, but may even degenerate.

The autonomic system. — The nerves coming off from the spinal cord and going to the muscles are called the spinal or skeletal nerves. Those coming from the brain are called the cranial nerves. There are other nerves which innervate the organs of the body and these come from both spinal cord and brain. At one time they were called "sympathetic* nerves" but now the name autonomic is given to these nerves. They supply the viscera, blood vessels, glands, and hair. It is seen, therefore, that skeletal muscles receive their stimulation from the central nervous system and the involuntary muscles of the body receive their stimulation from the autonomic system. Now the motor nerves supplying the skeletal muscles come from cells which lie in the ventral part of the spinal cord; the glands and smooth muscle of the viscera receive their innervation from nerves which come from ganglions which lie outside the spinal cord. The difference between the two systems in type is shown in Figure 173. The neurons running to the visceral organs usually have their cell bodies grouped in ganglia and this arrangement gives rise in certain places to a mass of nerve tissue which receives the name plexus. Hence, we have the solar plexus, the cardiac plexus, the splenic plexus, etc. (Fig. 175). The ganglia and plexuses of the autonomic system are connected with the brain and spinal cord by neurons whose cell bodies lie within the spinal cord. It is to be noticed, therefore, that there are two sets of neurons of this system; one from the cord and brain to the ganglion sometimes called the pre-

ganglionic neuron; and one from the ganglion to the viscera and gland and sometimes called the postganglionic neuron. This arrangement is shown in Figure 174. This figure should be studied with reference to the arrangement of the three divisions of this system. The name autonomic has been suggested by Langley and indicates that the structures

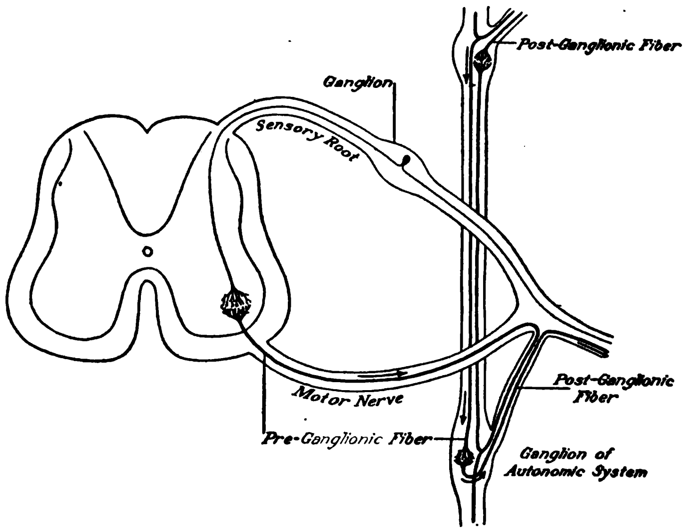


FIG. 173. — The preganglionic fibers of the autonomic system leave the motor root and run to the ganglion.

supplied by these nerves are not under voluntary control. In addition only a part could be classed under the old heading of sympathetic. So it is that there are given three divisions, the thoracico-lumbar* (sympathetic), the cranial, and the sacral.*

Thoracic-Lumbar Division. — The second division has the largest distribution. It sends fibers to the eyes and causes dilatation of the pupils. To this division belong the accelerator nerves that go to the heart (Figs. 174, 175). They cause it to beat faster. They also carry impulses to

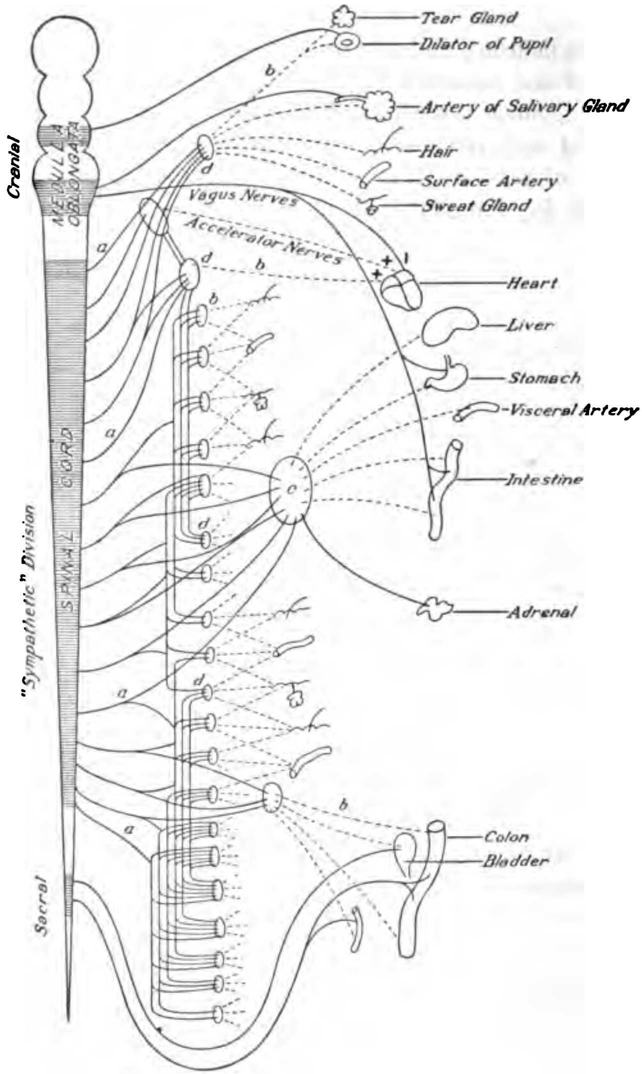


FIG. 174. — Diagram of the important parts of the autonomic nervous system. (*a*) preganglionic fibers; (*b*) postganglionic fibers; (*c*) plexus; (*d*) ganglia situated outside the cord; spinal cord and medulla and the parts to which the fibers go.

the muscle of the arteries and so make possible vaso-constriction. The stimulation of the fibers which go to the muscles of the hair causes the hair to stand on end. It is also known that the stimulation of these nerve fibers occurs

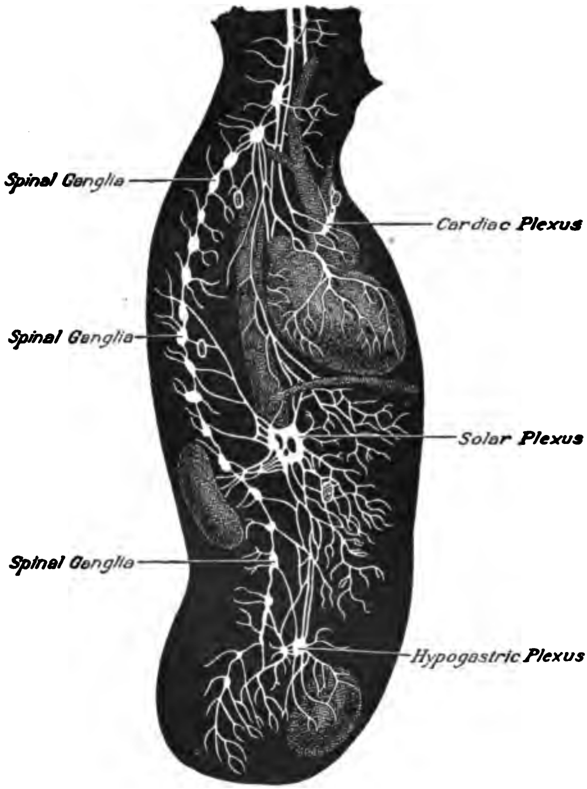


Fig. 175. — Diagram of trunk showing one of the two rows of autonomic ganglia near the spinal column and the plexuses.

under conditions which call forth emotional reactions. For example, when one is afraid, the hair stands on end; depressing conditions cause the flow of tears; the heart rate is increased at times of emotional disturbance.

Cranial Division. — The cranial autonomic serves to protect the body and to conserve its strength. The main part of the cranial division is the vagus nerve which runs to the heart and all the abdominal organs (Fig. 174). The cranial autonomic goes also to the salivary gland and causes it to secrete more saliva. It slows the heart and causes the contraction of the pupil. An analysis of these functions will show that this division serves to conserve the body. By slowing the heart, the cardiac muscle is given a chance to rest; by contracting the pupil the retina is protected; by stimulating the flow of saliva, gastric, and other digestive juices and by causing the contraction of the smooth muscle of the viscera, all the processes of digestion are accelerated and energy is produced with the least expenditure of energy. This makes for conservation of strength and reserve force.

Sacral Division. — The sacral division provides for the contraction of the smooth muscles concerned in emptying the organs which hold the waste of the body. These nerves control the action, therefore, of the colon, rectum, and bladder. This section may be thought of as rendering service to the body by keeping the waste removed and so it is of importance in body health and conservation.

Antagonism between the Sympathetic Division and the Cranial and Sacral. — This very complex mechanism for controlling the involuntary action of the bodily processes has a very interesting action, in that there is antagonism between the ends and central part of the system. Cannon says, "When the mid-part meets either end part in any viscus their effects are antagonistic." For example, the cranial fibers contract the pupil, the sympathetic fibers dilate it. The cranial fibers (the vagus) slow the heart, the sympathetic (the accelerator nerves) accelerate the heart. These opposed effects are indicated in Figure 174 in which + means contraction, acceleration, and – means relaxation, retardation.

Functions of the Autonomic System. — It is important to understand the working of this mechanism and to see how this knowledge can guide us in shaping our lives so that we may act in harmony with the mechanism of our bodies and not against it. It is always of value to act in accordance with the laws of health as well as the laws of the nation. From an understanding of this autonomic system, we appreciate why it is desirable to be happy and cheerful at mealtimes in particular. Emotional disturbance near meal times interferes with digestion because the sympathetic fibers carry the impulses concerned in rage, anger, fear, or pain, and these impulses will interfere with the impulses sent by the cranial division, supplying the digestive juices. So it is that all the processes of the body are assisted and accelerated by conditions that are cheerful. Happiness is a desirable stimulant and will work marvelously to keep the body well. One should not give expression to feeling of crossness, sullenness, pouting, anger, etc. Beyond the fact that they injure the body, of more importance is the fact that they make other people unhappy.

Afferent Nerves of the Autonomic System. — The afferent impulses through these nerves are slow and faint, seldom reaching beyond the spinal ganglia to the brain. Thus the circulation of the blood and the digestion of the food usually go on without our consciousness, but a very strong irritation may give rise to consciousness and pain in the abdominal organs, as in colic or in vomiting. Sensory impulses, signifying the needs of the cells and the necessity for movement in the arteries and intestines, are being continually sent to the spinal ganglia (Fig. 175). Only very strong impulses caused by disturbances that may injure the body, reach the brain, and cause pain.

Efferent Nerves of the Autonomic System. — The efferent nerves carry impulses which cause the epithelial cells of the glands to make their secretions, and the muscles of the

arteries and intestines to contract. They do this as a reflex response to the impulses going to the spinal ganglia from the sensory nerves of the system. At a flash of bright light the eye winks and the pupil contracts. The sweat glands secrete under the influence of warmth. It was formerly believed by physiologists that the "sympathetic" ganglia themselves sent the reflex motor impulses, but it is now believed that these come from the spinal ganglia. The "sympathetic" ganglia are supposed to reënforce the current and aid in the nutrition of the nerves that pass through them.

The brain. — The spinal cord can act only in response to impulses at the moment they are received. The brain can originate impulses which are not in direct response to a stimulus from the outer world. Its acts are apparently spontaneous, but they probably result from the combination of impulses previously received, which memory has enabled it to store up and retain. The brain not only causes action and directs the cord in giving order to voluntary movements, but it can restrain excessive action in the spinal cord. Self-control comes largely through the power possessed by the brain of restraining the spinal cells from sending out reflex impulses when strong and sudden impulses are received from the outer world. This is called the inhibitory power. If a door slams, a person whose brain is not exerting good control jumps suddenly.

Coverings of the Brain. — What facts did you learn about the skull, showing that it is well constructed for protecting the brain? The brain is covered by three membranes; the outer tough one lines the skull and the spinal canal. The next is thinner. There is a lymphlike fluid, called the cerebro-spinal fluid, within this membrane, so that the brain is surrounded by a kind of water bed. The third, and innermost, covering is hardly a membrane, for it is merely a thin network of fine blood vessels and connective tissue. It dips

down into every depression and fold of the outer layer of gray cells of the brain. This layer of gray matter is called the cortex. The folds in it are called convolutions (See Plate VII). Numerous folds signify great intelligence.

Weight. — The weight of the brain of the average man is forty-nine ounces (a little over three pounds), and of the average woman is forty-four ounces. The woman's brain is as large in proportion to the size of her body as a man's brain. Man's brain is surpassed in weight by the brains of only two animals. A whale, measuring seventy feet long, has a brain weighing only five pounds, and an elephant's enormous body is controlled by a brain of about eight pounds. Birds' brains are heavier in proportion to their bodies than the brain of any other animal. The brain grows very rapidly till the fifth year, then very slowly; the growth after twenty is very slight. Cromwell's brain is said to have weighed almost eighty ounces. Other great men have had large brains, but some great minds have inhabited very small brains. Quality is as important as quantity. The brains of idiots are usually very small.

The Cerebrum. — The chief parts of the brain are the cerebrum, the cerebellum, and the medulla oblongata. The cerebrum, or great brain, divided by a cleft into two parts, is highest in the skull, and covers all the other parts (Plate VI). It is composed of cells which lie in the cortex and fibers which pass from the cells to and from the spinal cord and cranial nerves (Figs. 176, 177). Sense-perception, consciousness, reason, and the will are located in the cerebrum. The cerebrum, as all other organs, is dependent upon circulation, respiration, digestion, and excretion. If the heart suddenly weakens its action very much, or if the vasomotor nerves allow the arteries to lose tone suddenly and increase their capacity for blood, the person faints, from a weakening of the circulation through the brain. Recovery is brought about by placing the head on a lower level than the body, so that

the blood may run to the brain with less exertion on the part of the heart. A violent blow on the head may make one insensible at once. By breathing chloroform, ether, or carbon dioxide, by taking morphine, the quality of the blood may be so altered as to bring sleep. In order that the brain may act, it must be constantly aroused by impulses from the outer world. Man loses consciousness as soon as his cerebral hemispheres cease to act; but his heart and lungs keep at work. It is curious that touching the cerebrum, or stimulating it with electricity, when it has been exposed by accident, arouses no sensation, although this organ is believed to be the seat of consciousness. This fact is of great interest, for it shows that impressions coming from the sense organs alone enter into consciousness. Fresh air, good food, and pure blood are essential for the best functioning of the cerebrum.

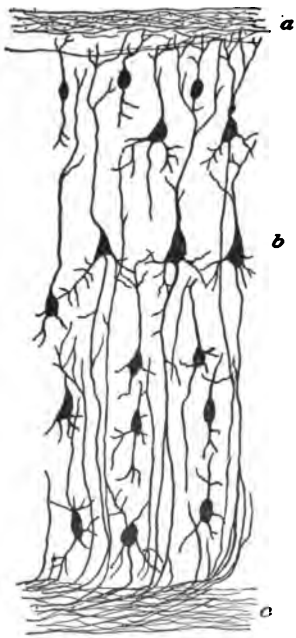


FIG. 176. — Microscopic diagram of the cells in the cortex of the cerebrum. *a*, external layer showing association cell, axone, and dendrites; *b*, pyramidal cell which sends off axone to enter the layer of medullated fibers *c*. The dendrites of the pyramidal cells pass into layer *a*.

Effect of Removing Cerebrum. — After destruction of the cerebrum, an animal may continue to live if fed by hand. It can run about, and swallow food placed within its mouth. It will be disturbed by a loud sound, such as the blowing of a horn. It might avoid a bright flame if placed in its path, but would go stupidly against other objects; but it is idiotic, for all acts of intelligence

cease. Its time is spent in sleep or mechanical wandering. A frog deprived of its cerebrum retains some more extensive powers than a warm-blooded animal. It starts to hopping when touched, avoids obstacles in its path, recovers its usual position when placed on its back, swims when thrown into water, and when placed on a board that is slowly tilted, it will preserve its balance by climbing to the top. These actions are reflex but of a higher order than a simple reflex act. The reason the frog continues hopping after being touched is that each hop, owing to the contact of the skin with the ground, excites another hop; the animal never begins to move of its own accord.

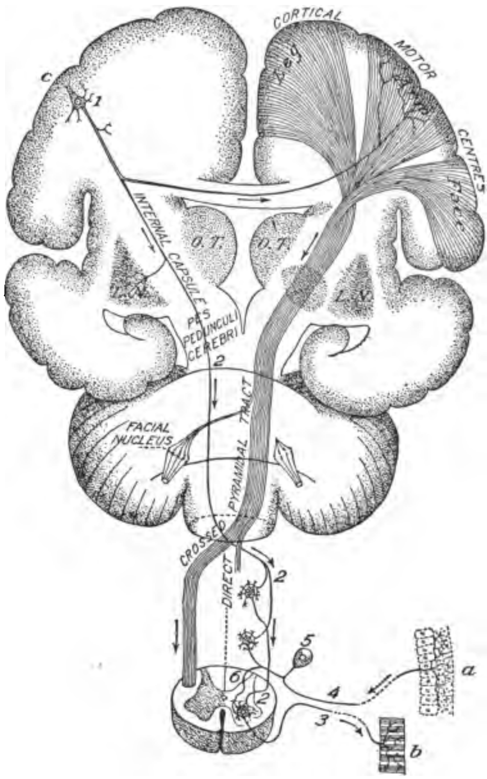


FIG. 177. — Diagram of the motor area and the motor tract in the brain. Find centers for leg, arm, face. Notice that most of the motor fibers from one hemisphere cross to the opposite side of the spinal cord; and if one half of the brain is injured, the opposite half of the body loses motion and sensation (paralysis). Trace nerve impulse from cell 1 in cortex at *c* to muscle at *b* (1–3). Trace reflex impulse from skin at *a* to muscle at *b* (4, 5, 6, 3).

Centers in the Cerebrum (Figs.

178, 179, 180). — When the part of the cerebrum that lies behind the ear is destroyed, a loss of the memory for the meaning of words may result. One can speak, but his words follow each other without sense or meaning. The sense of hearing is supposed to be located in the same region. The sense of sight is located in the rear part of the cerebrum. If

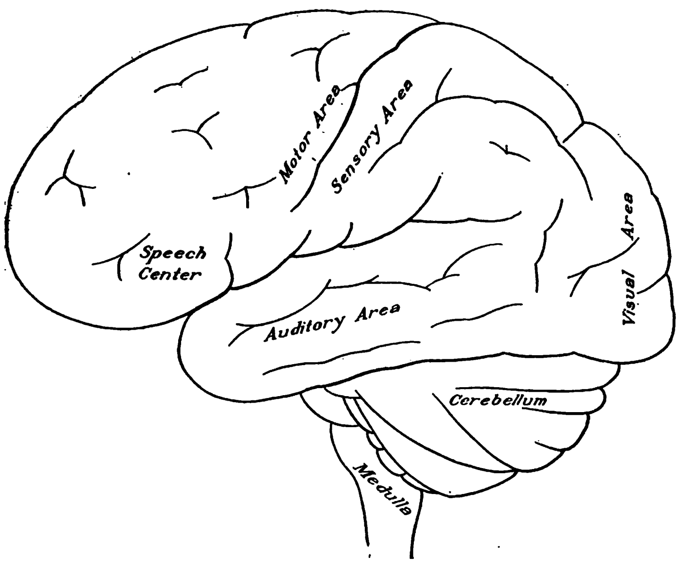


FIG. 178. — Localized areas of the cortex.

the rear part of the left hemisphere is destroyed, a man is unable to see anything to the right of his nose when his eyes are directed straight forward. The sense of smell lies at the base of the cerebrum toward the front (Figs. 179, 181).

A wounded soldier was brought to the surgeons with part of his skull torn away. The surgeons used an electric current to test whether the nerves were paralyzed. They were astonished to find that whenever the electric current was applied to the wounded part of the head, muscular

movements were excited. It was soon determined that by stimulating electrically a certain area of the cerebral cortex movements on the opposite side of the body can be excited. This area, called the motor area (Fig. 178), lies under the parietal bone, and extends from the top of the brain to the level of the ear. By experiments on monkeys and dogs, and by studying cases of accidents to the skull in human beings, this area has been subdivided. Stimulation of the lowest part causes movements of the face; of the middle part, the arm; and of the upper part, the leg, the movement always being on the side opposite to the stimulation (Fig. 180). When the lowest part of the area on the left side in right-handed persons is injured, the power of speech is lost. The comprehension of words and the ability to write, read, and hear language is not lost. With left-handed persons, this center is on the right side.

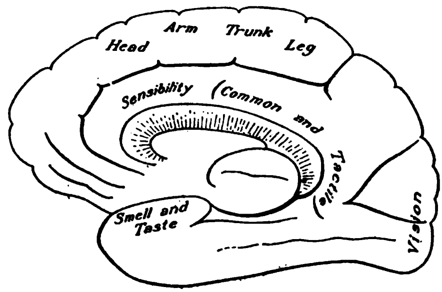


FIG. 179. — View of one cerebral hemisphere from between the hemispheres showing motor and sensory centers.

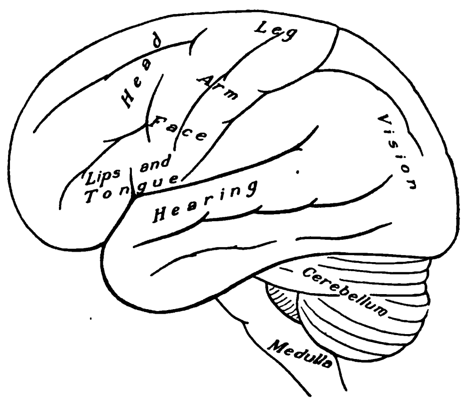


FIG. 180. — Motor and sensory centers. Most centers occur in both hemispheres, and if one is injured, the other will continue to work.

The Cerebellum. — The cerebellum, or small brain, is at the base of the skull behind. If a pigeon has its cerebellum removed, it is restless and has wide-open eyes; it flutters, but cannot fly. If the cerebrum is removed, leaving the cerebellum, it is stupid, but flies if thrown into the air. By placing the hand at the back of the skull between the occiput and the neck, you will cover the part occupied by the cerebellum. Coördination of the muscles is carried out by the cerebellum. You will to walk through activity of the cerebrum; the control of the muscles while walking is the function of the cerebellum.

Function of the Cerebellum. — The removal of the whole of the cerebellum from an animal does not produce death so long as the medulla is not injured, but the animal becomes weak and unsteady in its movements. If the cerebrum remains, the mental faculties are retained. Disease of the cerebellum in man produces dizziness and leads to a staggering, reeling gate. Hence it is believed that the function of the cerebellum is to aid the cerebrum in the control of the muscles. It brings about proper coördination of the muscular movements, so that in such movements as standing, walking, talking, the different muscles may each act at the right moment and with due force. The spinal cord also coördinates movements. For instance, if a frog is decapitated and left quiet for an hour or two, so that the spinal cord may recover from the shock due to the injury, it may be made to execute seemingly purposeful movements. If a drop of acid be placed on the flank of such a frog, the leg will be drawn up and the acid wiped off with the toes. But such coördinated movements are not accompanied by consciousness.

The Medulla Oblongata. — This, the most important of the cerebral ganglia, may be looked upon as the part of the spinal cord within the skull. It is just within the foramen magnum, and is intermediate in position and function be-

tween the brain and spinal cord. The spinal cord acts reflexly; the brain acts consciously. Conscious actions are those which are influenced by mental images or ideas. The medulla contains reflex centers and the centers of automatic action. This kind of action should not be confused with acquired reflexes, such as walking, to which the term "automatic" is sometimes applied. Automatic centers are those which are controlled by the condition of the blood. They are stimulated by an increase of carbon dioxide in the blood. The chief of these centers is the respiratory center of the medulla. If it is injured, death ensues by suffocation. The cerebellum or even the cerebrum may be injured or removed from the lower animals without causing death, but the smallest injury to the respiratory center kills the animal immediately. In cases of hanging, it is injury to this center that causes death. Another very important center in the medulla, controlled by automatic action, that is, by the varying condition of the blood, is the center for vasomotor nerves, which regulate the size of the blood vessels. It was previously learned that the vasomotor fibers belong to the autonomic system. There are also important reflex centers in the medulla, viz., the centers for the secretion of saliva, for swallowing, for vomiting.

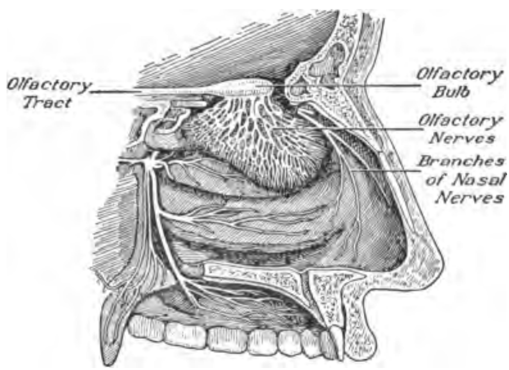


FIG. 181. — The olfactory nerve. The main nerve ends in the form of a bulb on the floor of the skull. The fibers branch from this bulb like the roots from an onion and spread out on the walls of the nasal chamber.

How Automatic Centers Work. — As the blood becomes deficient in oxygen and charged with carbon dioxide, the respiratory center is irritated and sends out impulses which cause deeper breathing. This improves the condition of the blood, and the respiration is quieter until the blood again loses oxygen; then stronger impulses are sent, and so on, thus regulating the condition of the blood automatically. The size of the blood vessels is regulated in the same way by the vasomotor center in the medulla, increase of carbon dioxide causing contraction of the surface vessels, decrease of it causing relaxation. Automatic acts take place in series. Reflex acts, such, for example, as walking, can take place in series also, but the first stimulus in reflex acts comes from without the body; in automatic acts from the blood. Figure 182 shows how a center controlling the secretion in a gland may receive impulses from the mucous membrane, from the brain, and then impulses are sent to the blood vessel to dilate and supply more blood and to the gland to begin to secrete.

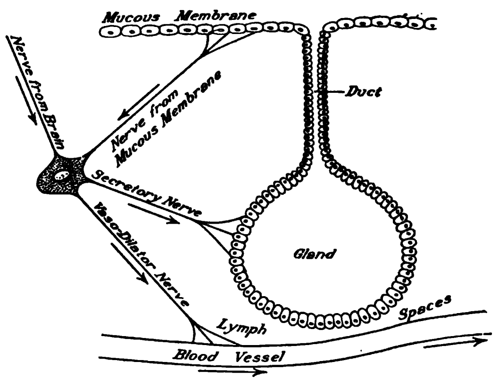


FIG. 182. — Diagram of a salivary gland. Showing automatic control (after Landois and Sterling).

GLOSSARY

Afferent (nerves). — Conducting inward toward the cord and brain.

Association. — Refers to nerve fibers that are concerned in purposely connecting different nerves or brain areas.

Autonomic. — Entirely independent and self-supporting in itself.

Cranial. — Relating to the cranium or the organ within the cranium, the brain.

Dendrites. — The tree-like branches of a nerve cell. The dendrite receives the nerve impulse from the axon.

Efferent (nerves). — Conducting away from the cord and brain. All efferent impulses are not motor and so efferent and afferent are more desirable terms than motor and sensory.

Medullated. — Covered with a soft fatty substance; that is, covered with a medulla.

Neuron. — A nerve cell with its dendrites and axon and hence the structural unit of the nervous system.

Peripherally. — Away from the center.

Reflex. — An act that goes on without the direction of the brain. It occurs before the individual is hardly conscious of the act. He may be conscious afterwards that he has acted but he has given no direction in the process.

Sacral. — Relating to the sacrum, near the sacrum or coming from the sacrum.

Sympathetic. — A part of the nervous system of the body that originally was supposed to be concerned in acts that were of a sympathetic character. The name now is autonomic because it is known that the chief characteristic of this system is the ability to carry on its activities without direction or help. Also its activities involve more than was connoted by the term "sympathetic."

Thoracico-lumbar. — A compound word referring to the thoracic and lumbar regions of the vertebral column.

CHAPTER XVI

HYGIENE OF THE NERVOUS SYSTEM

I. Connection between Body and Mind.
II. The Effect of Activity on the Nervous System.
III. The Effect of Sleep.
IV. The Effect of Fatigue.
V. The Effect of Alcohol.
VI. Improper Functioning of the Nervous System.
  Drugs and insanity
  Communicable disease and insanity
  Habits of mind and insanity
VII. Ten Golden Rules of Health for School Children.

Connection between body and mind. — The body and the mind are very closely related, are interdependent and are a unit. We have learned that muscle and nerve are interdependent. So it is with mind and body. Only rarely do you find a fine mind in a poor body; and in such an instance, the individual has lost largely the quality of bodily vigor which enables him to perpetuate his greatness. This unity of body and mind, this balance of physical and mental powers is essential for the welfare of the race. *Men and women should not only preserve, but if possible improve the quality of life they have, so that the race will be enriched.* There are many familiar examples of the connection between mind and body. Most men who have been great workers with their minds have also been zealous in using their muscles. There is a flexibility of mind and disposition that results from a mixed occupation which is in great contrast with the machine-like dullness and narrowness of mind

produced by a monotonous, one-sided occupation, whether mental or physical. Gladstone chopped down trees; Li Hung Chang when eighty years old walked three miles daily around the courtyards of his palace; Napoleon rode horseback; William Cullen Bryant, upon rising in the morning, swung a chair around his head, took wand exercise with a cane, and practiced other gymnastics. He walked five miles to his work.

The connection between body and mind is readily illustrated. The pulse rate is affected by every emotion. Shame causes the blood vessels of the face to dilate. Painful emotions excite the activity of the lachrymal* or tear glands. Joy increases ease of movement. If an excited or angry man who is walking to and fro sits down, his excitement decreases. A starving man and one suffering from fever have hallucinations.* The Romans had the proverb "a sound mind in a sound body." The care of the body for the mental effect as well as for the sake of the body itself, is only gradually regaining the high place it held among the Greeks and the Romans, a place which it lost during the Dark Ages. "Hysteria* and nervous exhaustion are the fruits not of over-work, but of lack of varied and interesting employment. The absurd opinion that hard work is menial and low, leads to most pernicious consequences. The girl who, turning from brain work to manual labor, can cook, scrub, wash, and garden, invites the bloom of health to her cheeks; while the fine do-nothing lady loses her good looks, suffers from the blues, and is a nuisance to her friends and a misery to herself."

The effect of activity on the nervous system. — If the cells of any tissues are not active in the performance of the work for which they are intended, they become weakened. It is the same with the nervous system. Fresh and new sensations are necessary for the health of the brain; those mental faculties that are used become strong. Unused

muscles become flabby and ill-nourished because the circulation in them is weakened; the circulation in inactive nervous tissue also becomes less active. Mental activity strengthens the nervous system and the body in general. If one protects his sensory nerves by too warm clothing and never lets the cold air strike them, they become weakened and unreliable and allow the blood vessels to lose tone. They are likely to do strange things with the circulation, causing colds and disease. If, because of pulpy or soft food, the nerves of the alimentary canal are not stimulated mechanically, peristalsis is weakened and the intestine becomes clogged. The loss of tone in the circulation and the sluggish peristalsis, with the troubles that follow, can often be improved by taking a cold bath every morning. The stimulus to the sensory nerves spreads reflexly to the vasomotor nerves and to the autonomic fibers of the intestine; these are "toned up" and restore activity to the involuntary muscles.

The effect of sleep.—The cells of the body with all their industry are not tireless, and at intervals require rest (Figs. 183, 184, 185). During sleep the heart beats more slowly, respiration is less rapid, the muscles in general are relaxed, the gland cells diminish their secretions, and digestion is slow. The production of heat is lessened and the body must be protected from cold. Yet consciousness is the only function entirely in abeyance. The sound of a passing vehicle quickens the pulse of the sleeper without awaking him; if he is touched, he moves. Sleep is deepest during the second hour, and it then takes a much louder sound to awaken him than during later hours. Sleep becomes gradually lighter until awakening occurs. When consciousness is partly present, the condition is called dreaming.* In somnambulism,* the sleeper may talk or walk as he dreams.

There are different explanations given for the cause of sleep. Some believe that it results from the accumulation of waste products in the body; it is also held that it is due

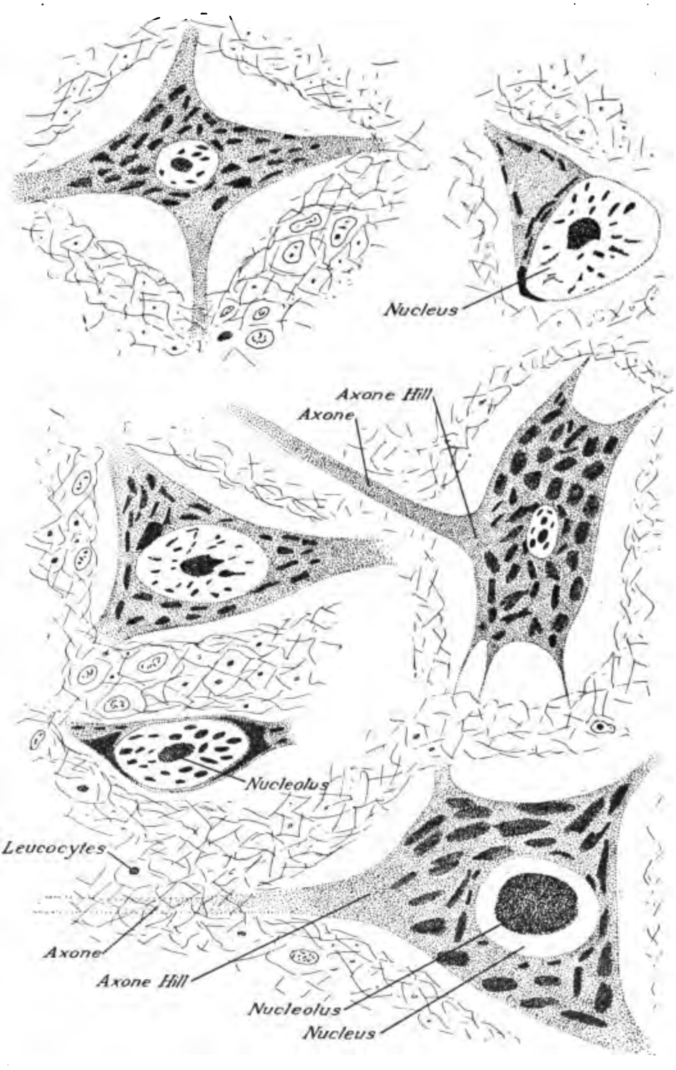


Fig. 183. — Showing various types of nerve cells (bodies) from the spinal cord. These cells are rested.

to lack of circulation in the brain. Now the process is not fully known, but it is perfectly clear that individuals require sleep (Figs. 184, 185). If sleep is interfered with, the body is injured. There should not be in this as in so many other things the disposition to make yourself and your friends uncomfortable by the insistence at all times on a certain number of hours. There are occasions when it may be very

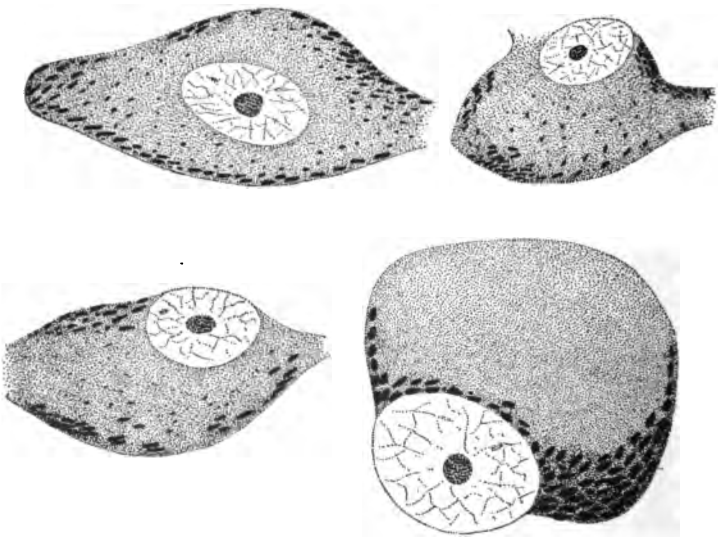


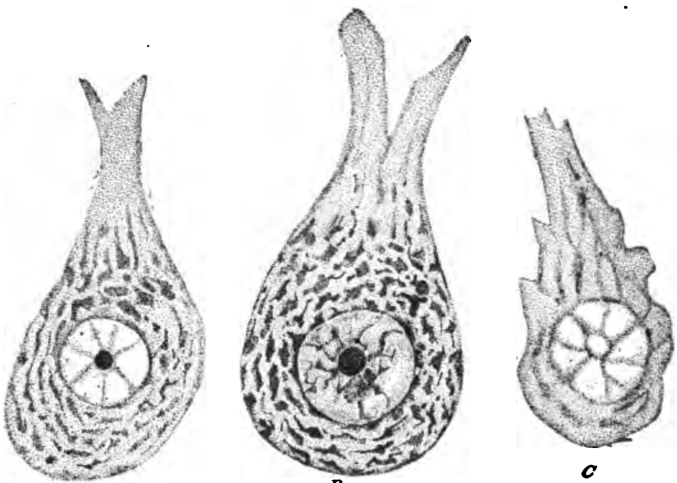
FIG. 184. — Tired nerve cell bodies from the spinal cord. These cells show the nucleus to one side, the chromatin* decreased in amount and at the wall of the cell. Compare with the cells shown in Figs. 183 and 185.

desirable to take less sleep than customary, and we should be able to go with less sleep for a time in the accomplishment of important work. The number of hours of sleep for children of different ages is given on page 326.

For a sound nervous system, nothing is so indispensable as plenty of sound sleep. It is necessary for growth and repair of the cells (Fig. 185). Infants sleep almost all the time; children of four or five, nearly half the time; those of

ten or twelve, ten hours; most college students require eight hours, and this amount is required by most adults.

The morning should bring a feeling of vigor. If we wake tired and discouraged, there is something amiss. It may be that there was over-exertion the day before and the sleep has not been long enough, or that we have been up too late or have eaten improper things. If the last is the case, there is apt to be a bad taste in the mouth on awakening. By



A B C

FIG. 185. — Brain cells at rest, in action, exhausted (Crile).

going to bed at the same hour every night, the habit is formed of dropping off promptly and soundly to sleep. A cheerful state of mind with resolute avoidance of worry promotes sound sleep at night. The sleeping room should be cool, but it is not necessary that water freeze "in the pitcher." It should be well ventilated, the window being left open even in moderately cold weather in the northern states, and in very cold weather in the Gulf states, unless the room is loosely built.

The effect of fatigue. — Waste products produced in one part of the body are carried by the circulating blood, before they can be removed, to all parts of the body. Fatigue in one part causes a loss of efficiency in other parts. It is well known that the boy who plays football for two hours in the afternoon is unable to study in a satisfactory way in the evening. Such fatigue is natural and healthful. After the period of rest, the body is recreated and the taking in of food by the body cells, called assimilation,* results in the organization of the food into living tissue. It is known that mental activity does not greatly increase waste substances, but that does not mean that one cannot overwork mentally. The feeling of fatigue which comes from tired eye muscles and tired joints should indicate the need for a change of activity. This change will be satisfied best by physical exercise of the game or sport type.

The effect of alcohol. — As alcohol acts on many organs through its action on the nervous system, it would naturally be supposed that the nervous matter itself would be injured, and such is the case (Figs. 229, 230). In fact, it is upon the delicate nervous system that its most destructive effects are wrought. One of the first effects of alcohol is flushing of the face and a feeling of warmth on the surface of the body. This is due to the quickened action of the heart and the dilation of the small blood vessels from the effects of alcohol on the nerve centers controlling these organs. The mind is at first more active, because the little vessels of the brain are dilated and blood is sent more freely to that part. A little later the alcohol begins to disturb the reflex and coördinating powers of the nervous system, and ordinary muscular movements are performed imperfectly and with difficulty. The nerve centers seem to be attacked and paralyzed progressively by alcohol, beginning with the highest and proceeding toward the lowest. The will power and judgment first become paralyzed, and only the emotional and impulsive instincts

of human nature are left; these, being no longer under control of reason and judgment, are likely to cause the individual to act in an irrational manner. In the last stages, consciousness and volition are lost, and only that part of the nervous system in the medulla which governs circulation and respiration remains active. In other words, the man is "dead drunk." A large quantity of alcohol may produce death by paralyzing even these nerve centers, thus stopping all organic functions. This overaction and irregular action of

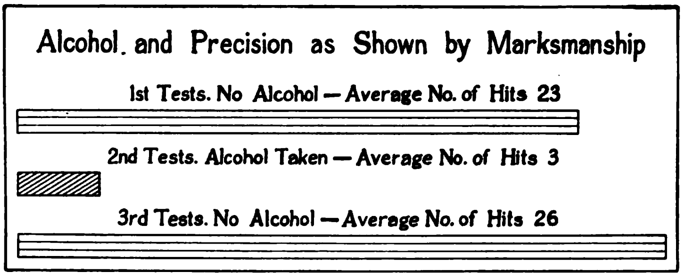


FIG. 186. — Fewer hits were made on the alcohol days, but the soldiers *thought* they were shooting better.

the nerves, when repeatedly occurring, has the effect finally of deforming or destroying the nerve tissue.

It is well known that skill in a movement or act is developed by a training of the nervous system. Now alcohol lessens skill and precision in fine work. There is no work or play that man performs that cannot be performed better without alcohol. In tests of target shooting, the advantage of abstinence and the disadvantage of using alcohol were clearly shown by experiment. In this test (Fig. 186), during the first series no alcohol was used; in the second series two thirds of a wine glass of brandy was taken 20 to 30 minutes before shooting and an equal amount of alcohol in punch on the evening before. No one who aims to achieve a place in the world and in the respect of friends

can afford to use alcohol in any form. Its effect on the nervous system is especially disastrous.

Alcohol lessens skill and precision in fine work where head, hand, eye, muscles, and nerves must work together for deftness and accuracy.

It is common knowledge that a musician, who is indulging in alcohol, will make more mistakes in playing. The fine adjustments and coördinations are then no longer possible. Those who look forward to having power over and control of the body should guard against the danger of alcohol.

Improper functioning of the nervous system. — Nearly everyone has known of some one who has gone insane. Such disease of the mind was little understood in the past, and insane persons were thought to possess evil spirits. Insanity * is usually thought of as coming quickly, and the most fantastic causes are given for its occurrence. Now the important thing for us to remember is that insanity usually develops slowly and its causes are well known. Insanity is much more frequent than is generally supposed, and in the state of New York about one in every 200 of the adult population is in an insane hospital. In ten years insanity in this state has increased 104 per cent.

Drugs and insanity. — Opium,* morphine,* and cocaine * cause a large proportion of the insane in every state. Alcoholic insanity may be caused by the regular use of alcohol even in moderate quantities which do not produce intoxication. It is stated that 30 per cent of the men and 10 per cent of the women in the state hospitals are suffering from conditions due to alcohol. In states where there is prohibition, the amount of insanity is much less. This is scientific information and has the support and belief of the highest medical authorities. These poisons, alcohol, opium, morphine, and cocaine make up the principal parts of many patent medicines. This is another reason for forbidding

their use because they often weaken the mental powers and produce insanity.

Communicable diseases and insanity. — Mental disturbance of a serious nature may follow certain diseases. The poison from typhoid fever,* diphtheria,* and tuberculosis * may so injure the nervous system that complete recovery does not occur. Many cases of insanity are produced by a specific communicable disease that is contracted through immoral acts. Those who are weak enough not to control themselves may look forward to the possibility of "softening of the brain," or, as it is called by doctors, general paralysis.

Habits of mind and insanity. — Habits of mind are important factors in producing mental disturbance. The state of mind that is most favorable for the health of the nervous system is the one in which the individual is satisfied with life and is not nursing the misfortunes that happen to befall him. It is dangerous to brood and pout over slights, disappointments, and injuries. Such unwholesome mental reaction if persisted in may tend toward insanity. Some people think that their disposition is fixed like the color of the eye, but it is not so. A cheerful, optimistic, friendly, and happy disposition may be trained and achieved.

Hard work alone rarely causes a breakdown of the nervous system, unless there is associated with it loss of sleep and worry. Henry Ward Beecher once said, "It is not hard work that kills men; it is worry."

Ten Golden Rules of Health for School Children [1]

I. Sleep — get as many hours in bed each night as this table indicates for your age. Keep windows in bedroom well open.

[1] Proposed by Dr. Thomas D. Wood, Columbia University.

HOURS OF SLEEP FOR DIFFERENT AGES

AGE	HOURS OF SLEEP	TIME IN BED
5–6	13	6 P.M. to 7 A.M.
6–8	12	7 P.M. to 7 A.M.
8–10	11½	7:30 P.M. to 7 A.M.
10–12	11	8 P.M. to 7 A.M.
12–14	10½	8:30 P.M. to 7 A.M.
14–16	10	9 P.M. to 7 A.M.
16–18	9½	9:30 P.M. to 7 A.M.

II. Eat slowly — never between meals. Chew food thoroughly. Drink water with meals but never when there is food in the mouth. Drink water several times during the day.

III. Brush your teeth at least once a day. Rinse mouth out well with water after each meal.

IV. Be sure your bowels move at least once each day.

V. Take a warm, cleansing bath with soap once or twice a week. Take a tepid or cool sponge (or shower) bath each morning before breakfast and rub body to a glow with a rough towel.

VI. Keep clean — body, clothes, and mind. Wash your hands always before eating.

VII. Play hard and fair. Be loyal to your team mates and generous to your opponents.

VIII. Study for keeps.

IX. Do all you can to help keep your school and your home clean and attractive.

X. Be cheerful and do your best to make the world a better place to live in.

APPLIED PHYSIOLOGY

Exercise I

1. Why is it best to change from very absorbing work to work of less interest a while before retiring?
2. Why is the power of habit a blessing? A danger?

3. How does travel often cure a sick person when all else fails?
4. Why should we never study immediately after eating?
5. Is it better for children to play or to take exercise?
6. What causes the peristaltic action of the stomach?
7. Is one more likely to sleep soundly who does his brain work in the forenoon and muscular work in the afternoon than if he reverses the order?
8. How do fatigue and sleep affect the nervous system?

Exercise II

9. How does anger cause indigestion?
10. Does perfectly comfortable clothing from head to foot contribute to one's ease in company?
11. Does uncomfortable clothing make one self-conscious?
12. Is it as important to have the shoes and the clothing perfectly comfortable when going out as when staying at home?
13. Would you get more rest by sleeping for four hours undisturbed, or by sleeping eight hours but being awakened every half hour by some noise, and going immediately to sleep again?
14. When one sits with the leg under the body, why is it that the compression causes a tingling sensation or paralyzed feeling in the foot?
15. Do the girl, who frets over washing the dishes, working with an unwilling mind, and the boy who, while he is sawing wood, is wishing to go to a baseball game, do their work with more or less fatigue than if they worked cheerfully and willingly? Why?
16. What are the causes of improper functioning of the nervous system?

Exercise III

17. How is a sneeze a protective act?
18. Why may a dyspeptic digest a large Thanksgiving or Christmas dinner when he often has trouble with an ordinary dinner?
19. Why is it more difficult for an adult to learn to speak a language than for a child? Why do adults find drawing and languages more difficult to acquire than history and mathematics?
20. In what two ways may opening a window when a student is becoming dull and drowsy at his books enable him to wake up and study with ease?
21. Muscles may be classed as minor, such as those of the eye, voice, hand; and major, such as those of upper arm, leg, trunk.

Why is the use of the minor muscles exhausting to the nerves, while the use of the major muscles strengthens the nerves?

22. Why do you throw cold water upon a fainting person?

23. Why may cold feet cause sleeplessness?

24. Why does constant moderate drinking undermine the health more than occasional intoxication?

25. The vasomotor nerves control the size of the blood vessels. Which nerve centers control these nerves? Why does a draught blowing on the back of the neck often cause a cold?

LABORATORY EXERCISES

Reaction Time. — The nervous system is arranged to protect the body from injurious conditions affecting it through its environment. This protection is shown when the eyes are closed to shut out the light that is too bright, when the hand is thrown in front of the face to ward off a thrown missile, and when the hand is withdrawn

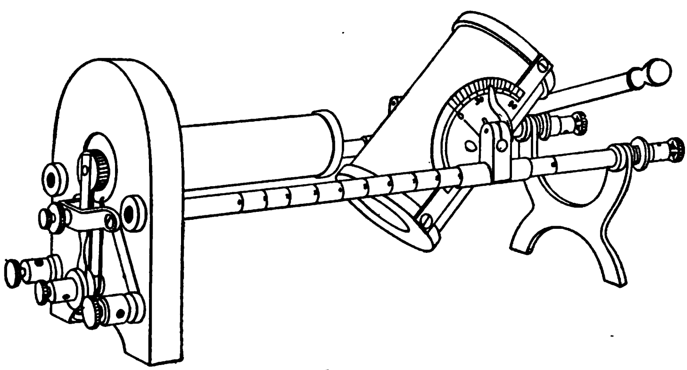


FIG. 187. — The inductorium. (The set screw holding the trunnion block tube against the side rod is not shown.)

on coming in contact with a hot stove. These are a few of the many instances of the protective reactions of the nervous system. Now the quickness of this reaction varies in different people, and the length of the time from the moment the outside stimulus is received and the body reacts is shorter or longer depending on the activity of the nervous system. This time is called the *reaction time* and is capable of measurement.

Experiment 1. To study the reaction time of the nervous system.

Material. — Inductorium, signal magnet, copper wires, electric batteries, kymograph, and keys. (Figs. 187, 188, 189, 190.)

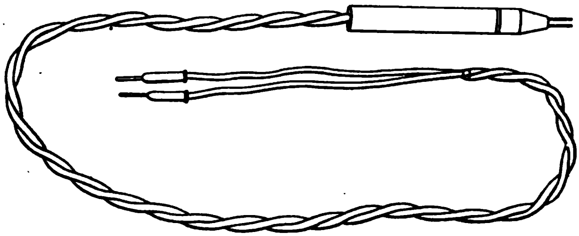


Fig. 188. — Electrodes. About two fifths the actual size. The electrodes are attached to the inductorium.

Method and observation. — Arrange a signal in the primary circuit of the induction apparatus with the two keys. Place the kymograph with smoked paper in contact with the recording point of the signal magnet. Let the subject hold the electrodes of the inductorium on the tip of the tongue with one hand and with the other hold down the one key. The experimenter will then spin the drum and close the other key. This closing of the key will make the circuit and hence will produce an electric shock. When the subject feels the shock on the tongue, he breaks the circuit by opening his key. This closing and opening of the circuit produces a movement of the signal which is recorded on the kymograph, and so there is a graphic record of the time the stimulus was received and the moment the response was given. This interval is the Reaction Time.

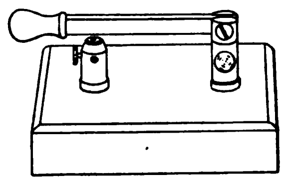


Fig. 189. — The simple key; about three eighths the actual size.

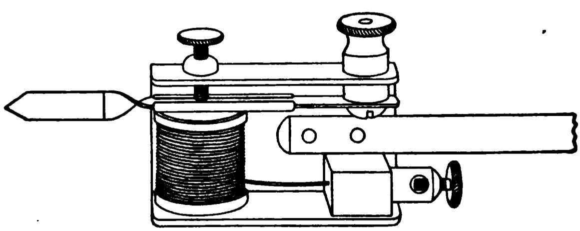


Fig. 190. — The signal magnet.

GLOSSARY

Assimilation. — The last act of the process of nutrition. It follows digestion and absorption. After the food elements are digested and absorbed, the transformation of them into an integral part of the cells of the body is assimilation.

Chromatin. — The coloring matter of the nucleus. The chromatin contains the essential elements of the cell and is important in reproduction of the cell.

Cocaine. — A white, bitter, crystalline alkaloid with the formula ($C_{17}H_{21}NO_4$). It produces loss of feeling when injected into the skin.

Diphtheria. — A disease caused by the *Bacillus diphtheriæ.* The organisms grow on the mucous membrane of the throat, larynx, and nose and produce toxins which circulating in the blood cause the injury to the heart and nerves and the resulting symptoms.

Dream. — A succession of mental images, usually incoherent and confused, that come in sleep.

Fever. — A general disturbance of the body characterized by an increase in body temperature. Often preceded by a chill and followed by quickened pulse and respiration. The communicable diseases all produce some fever.

Hallucination. — An apparent perception with no corresponding external object. Sights seen and sounds heard without there being any object or cause of sound, illustrate the condition.

Hysteria. — A nervous state in which the individual rapidly changes from laughing to crying accompanied with a choking sensation in the throat.

Insanity. — A condition of the mind brought about by diseased processes in the brain or nervous system. The individual lacks the ability to think and act in the way which is considered by most people to be sane.

Lachrymal. — The gland which secretes tears; the duct which carries them over the eye ball; the name of the secretion itself.

Morphine. — A bitter, crystalline, narcotic alkaloid with the formula ($C_{17}H_{19}NO_3$). It is a derivative of opium.

Opium. — A product of the unripe capsules of the poppy. Chemically it is a mixture of different alkaloids, chief among them being codein and morphine.

Somnambulism. — Performing the act of walking and other purposive acts during sleep.

Tuberculosis. — A disease caused by the *Bacillus tuberculosis.* This organism may attack almost any structure in the body. There may arise tuberculosis of the lungs, of the liver, of the brain, of the kidneys, of the intestines, and other organs.

Typhoid fever. — A disease caused by the *Bacillus typhosus.* This organism attains entrance to the body through water, milk, or food that has been contaminated by one sick with the disease.

CHAPTER XVII

SENSATION AND THE SPECIAL SENSES

I. Classification of the Senses.
II. The Sense of Taste.
III. The Sense of Smell.
IV. The Sense of Sight.
  The external parts of the eye
  The interior structure of the eye
  The act of accommodation
  Regulation by the iris of the amount of light admitted
  Defects of vision
  Care of the eyes
V. The Sense of Hearing.
  Structure and function of the ear
  Care of the ear
VI. The Sense of Touch.
  Temperature
  Pain
  Pressure
VII. The Muscular Sense.
VIII. General Sensations.
  Hunger
  Thirst

Classification of the senses. — In animal life the development of the nervous system has produced certain groups of nerve cells for the purpose of carrying on particular tasks. The eye is a nerve structure which has undergone a remarkable development so that man may be more familiar with his environment. The endings of a nerve in the tongue make possible the distinction between sweet and sour, palatable and distasteful food. Sensory nerves in the skin

inform us regarding the objects in the world around us. The touch sensation is compound. It conveys qualities of pressure, warmth, cold, and pain. The temperature sensation is always projected externally to objects; the pain sense goes inward and is felt as a sensation* within the body. The sensory nerves in the skin have special endings and each nerve has special work to do. There are cold and warm, pressure and pain nerves and, when stimulated, each carries its own kind of sensation. Pressure nerve endings transmit a sense of pressure; cold endings carry a sensation of cold, etc. Sensory nerves also have endings in the muscles and these nerves on contraction of the muscle tell the brain how intense the contraction is and where the part has moved. Some of these fibers end in the cerebellum and this sense at work helps to maintain the balance of the body. It is called our muscle sense. In addition, there are certain common sensations, such as hunger and thirst. We feel them as existing within the body.

- Sensations
  - Special Senses
    1. Taste
    2. Smell
    3. Sight
    4. Hearing
    5. Touch
       - Temperature
         - Warmth
         - Cold
       - Pain
       - Pressure
    6. Muscle sense
  - General Senses
    1. Hunger
    2. Thirst

The sense of taste. — It was mentioned that the tip of the tongue has a very keen sense of touch. The tongue is a very muscular organ, and when we are eating, it helps to keep the food between the teeth; it also does the chief part of the work in the beginning of the process of swallowing. But perhaps its most important function is to afford a home for the nerves of taste. These nerves consist of a branch of the fifth pair of nerves, which are distributed over the

front part of the tongue, and the ninth pair, which go to the back part of the tongue (Fig. 171). Although we often speak of food as being palatable, the sense of taste in the palate is very feebly developed.

What we call flavors affect us through the sense of smell. If the nostrils be held closed, a piece of onion placed on the tongue does not have the "taste" of onion at first, nor at all, unless particles are wafted up and pass through the pharynx into the nose. An apple is, under the same conditions, as tasteless as an Irish potato. If the nose is held shut, ground coffee placed upon the tongue loses its flavor and is as tasteless as sand, if the tongue is wiped dry. The way to make these tests is to obtain the articles and have them given to you for tasting without knowing which you are getting; then find whether or not you can tell the difference.

Substances, in order to be tasted, must first be dissolved on the tongue. The tip of the tongue is most sensitive to sweets and salines, the back part to bitters, and the sides to acids.

The sense of smell. — In quiet breathing most of the air passes along the lower parts of the nasal passages, just above the hard palate. Fibers of the olfactory nerve end mostly in the higher part of the nasal passages. When we wish to test an odor, we sniff, that is, we take a sudden inspiration by jerking the diaphragm down. A volume of air larger than usual rushes in, more of it passes over the parts of the walls in which the olfactory fibers are located. It is necessary that the substance producing the odor be in a very finely divided condition, probably gaseous.

Smell has its source in the beginnings of the respiratory passages, just as taste is at the gateway of the alimentary canal; and just as taste by its influence on the salivary and gastric glands, greatly influences digestion, so the sense of smell greatly influences the respiratory acts. The breath-

ing of a pleasant odor increases the depth of the breathing. Pleasant odors, as of flowers and of fresh country air and of the forest, contribute to our health and well-being. Why do foods lose flavor when one has a very bad cold in the nose?

The sense of sight. — The eye brings to the brain from the external world pictures of form, color, and movement. Without the eye, color and movement could not be ascertained and form would be only partially sensed. How would form be known in part? This marvelous structure, the eye, is set into a hollow, formed by the bones of the skull. The camera in structure and function is similar to the eye. Familiarize yourself with the parts of a camera and identify these with parts in the eye.

The external parts of the eye. — The eye is a globular organ, set in a bony socket. It is controlled in its movements by muscles, protected from dust and dirt by the lids and lashes, and on its exposed surface, the conjunctiva, it is moistened by a secretion from the lachrymal gland. These structures form the external parts of the eye and will be described before the internal structure of the eye proper will be given.

The Oculo-motor Muscles (Fig. 191). — The eyeball is capable of being turned in all directions by means of six slender muscles which begin in the back part of the orbit. Four of them are straight. The one above turns the eye upward, the one below turns it downward, the one toward the nose turns it inward, and the one toward the temple turns it outward. The other two are oblique. The superior oblique muscle passes forward through a loop which serves as a pulley near the inner upper front part of the orbit (Fig. 191). It rotates the eye in one direction, and its antagonist, the inferior oblique muscle, rotates it in the opposite direction. "Cross eyes" are caused by too great contraction of the internal straight muscles, and "wall eyes" are caused by too great contraction of the external straight

muscles. The defects may be remedied by a skillful surgeon, who cuts the proper muscle with a suitable instrument, and permits it in healing to become attached to another point farther back.

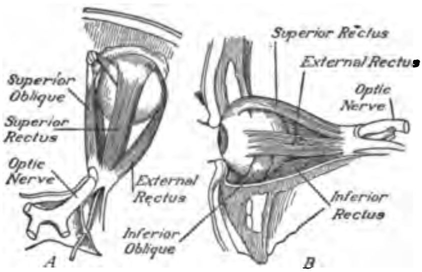


FIG. 191. — *A*, the muscles of the right eyeball (viewed from above). *B*, the muscles of the left eyeball (viewed from the outer side).

A person is blind while the eyes are moving. Watch while some one in front of the class tries to move the eyes gradually and uniformly across the field of vision. Do the eyes move by jumps or steadily? The motions of the lids and eyeball give the expression of the eye. The eyeball itself has hardly more expression than a glass eye.

We judge the distance of objects by the lines of convergence of the two eyes. This convergence is accomplished by the harmonious action of the eye muscles. A boy with one eye has difficulty in knowing when a ball thrown will reach his hand. When we look at a solid object, each eye sees a little more of the object on its side than does the other. Thus two eyes make it easier to distinguish bodies. By taking two photographs of a solid scene from slightly different points and arranging them so that the eyes look at the pictures separately but at the same time the idea of solidity

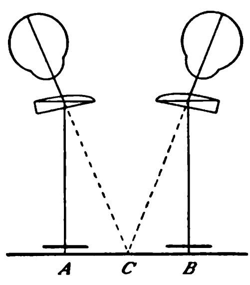


FIG. 192. — Diagram of a stereoscope. Two photographs, *A* and *B*, are seen combined at *C*. The rays of light from *A* and *B* are refracted by the prisms into the eyes so that they appear to come from *C*.

is given. The stereoscope* (Fig. 192) secures this arrangement.

The Lids. — The upper and lower lids protect the eye. They are supplied with muscles and can be moved very quickly. The upper lid has greater movement. From the edges of the lids grow hairs, called lashes. The lashes protect the eye from dust and are very sensitive to all pressure. The under surface of the lids is covered by conjunctiva in which are located glands which produce an oily secretion. This secretion prevents the rapid drying of the watery secretion that comes from the lachrymal gland.

The Lachrymal Gland. — The lachrymal gland is sometimes called the tear gland. It is located above the eyeball, between the ball and the bony arch on the side toward the temple. It is flattened and oval in shape, about three quarters of an inch in length. About ten small ducts lead from it and open on the under side of the upper lid. The secretion that it furnishes to the conjunctiva is formed continually. The tears pass across the eye and flow into two small ducts, the openings into which can be seen on the borders of each eyelid near the inner angle of the eye. They open into a canal which leads into the nasal passage (Fig. 193). When one weeps, why is it necessary to blow the nose frequently? At the ordinary rate of supply, the tears do not overflow, as there is a waxy secretion along the edge of the eyelid that turns them toward the ducts. When have you noticed a waxy secretion in the corner of the eye?

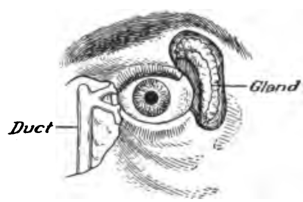


FIG. 193. — A front view of the left eye, with the eyelids partially dissected to show lachrymal gland and lachrymal duct to nose.

The Conjunctiva. — The eye is apparently set in a slit in the skin of the face, but this is not really the case. The skin of the eyelids turns inward over their edges and becomes

a thin, transparent, and exceedingly sensitive mucous membrane, called the conjunctiva. It is, like other mucous membranes, composed of epithelial cells. The conjunctiva goes back under the lid and over half the eyeball itself to the other lid, so that the eye is really behind the skin. When the eye is directed very much to one side, the conjunctiva is sometimes seen lying in wrinkles. The veins which we think we see in the white wall of the eyeball when the eye is "blood-shot" are usually in the conjunctiva, which is so transparent that we do not easily see it unless its vessels are swollen. Trachoma,* sometimes known as "sore eyes," is a disease of the conjunctiva. This serious infection of the conjunctiva is not infrequent among school children. This disease is very serious and affects the sight if not properly cared for. It is transmitted from child to child by use of the common roller towel, by borrowed handkerchiefs and other personal property that comes in contact with the face of the child. Always use your own individual towel and never lend or borrow a handkerchief.

The Health Department of the City of New York has issued the following bulletin for parents:

DEPARTMENT OF HEALTH

THE CITY OF NEW YORK

Instructions to Parents Regarding Trachoma

Trachoma is a contagious disease of the eyelids. If left untreated it is very dangerous to the eyesight.

It first attacks the inner surface of the eyelids, later it spreads to the eyeball itself and causes loss of sight.

In the beginning the eyes may be red and watery and they may, from time to time, contain matter, but often for a long time there are no symptoms that the person notices, and the disease is frequently first discovered by the doctor. It is very difficult to cure trachoma, and it is the more difficult the longer the disease has lasted. For this reason trachoma should be detected as early

as possible. It is contagious when secretion, that is to say "matter," is present. This secretion is conveyed from the eye of the person affected to the eye of the healthy person and thus sets up the disease. The secretion is for the most part conveyed by means of towels, washrags, and handkerchiefs, and persons with trachoma should always be careful that their towels, washrags, and handkerchiefs are used by themselves only. It is not on the street that trachoma is transmitted from one person to another, but generally in the home, and it is, therefore, in the home that the greatest precautions should be taken.

Children who have trachoma are not allowed to attend school unless they are regularly treated.

If your child has sore eyes, take it to your doctor or to a Dispensary* at once.

The interior structure of the eye. — The eyeball (Fig. 194) is a globular chamber filled with transparent fluids. This

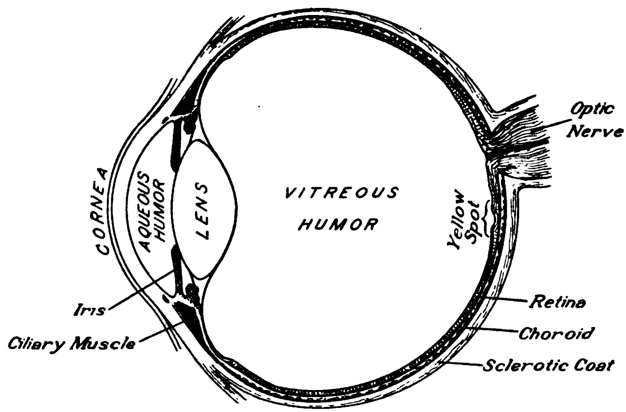


Fig. 194. — The anatomy of the eye.

chamber is divided into two compartments (Fig. 194) by a semi-solid crystalline* substance called the lens,* and a muscular diaphragm (Fig. 195), the iris. The wall of the eye is made of three layers of tissue, called coats of the eye.

Coats of the Eyeball. — The sclerotic* coat is the tough white outer coat of connective tissue. It preserves the

shape of the eye and serves for the attachment of the muscles. This coat is pierced in only one place, and that is for the entrance of the optic nerve. It is continuous over the front of the eye, where it becomes transparent, and is called the cornea. You can see the cornea bulging out in the front of a classmate's eye if you look at it from the side. The middle coat, the coat just within the sclerotic, is the choroid.* It consists of pigment cells and blood vessels. The choroid coat does not cover completely the whole ball. It is not over the cornea, but at the beginning of the cornea the choroid turns toward the center of the eye and forms the iris. The iris has an opening called the pupil,* and this opening because of small muscles can change in size. The iris changes the opening of the pupil to allow just sufficient light to properly stimulate the optic nerves. When the light is dim, the pupil is opened wider and in bright light it is contracted to a small opening. The point where the choroid leaves the sclerotic coat to form the iris marks the attachment of the lens to the choroid. These two structures, iris and lens, divide the chamber of the eye into two compartments. In the anterior chamber is the aqueous humor;* in the posterior, is the vitreous humor.*

The retina * is the third or innermost layer of the wall. It lines the chamber. It is composed of the end filaments of the optic nerve. These are a hundred thousand or more in number. The ray of light on coming into the eye stimulates these sensory endings of the optic nerve. To receive this stimulus of the light ray is the function of the retina, and to transmit it to the brain, is the function of the optic nerves (Fig. 197).

The Aqueous Humor. — The aqueous humor is a transparent liquid. This liquid gives firmness to the front part of the eye. It allows rays of light to pass through without deflection.

The Vitreous Humor. — The posterior compartment is

the larger and main part of the chamber. The vitreous humor that fills this space is a perfectly clear liquid.

The Crystalline Lens. — The lens (Fig. 194) is a perfectly clear transparent structure, jelly-like in consistency. It is suspended by ligaments from the choroid at the place where the iris begins. The ligament is called the suspensory ligament.

Take a lens that is rounded outward (convex)* on both sides, such as a hand magnifier, or even a strong lens from an old person's spectacles. Hold this up on the side of a room opposite to a window and catch the image* of the window on a white cardboard held back of the lens. This illustrates how the image of an external object is formed by the crystalline lens upon the retina. If some one stands up in the window, does he appear in the upper or lower part of the image? If he moves to the right, in what direction does his image move? The reversals are explained by the crossing of the rays of light as they pass through the lens. If two lenses of different thickness be used, it will be found that the cardboard must be moved close to catch the image from the thicker lens. The lens serves to refract the rays of light and focus them to produce a clear image.

The Yellow Spot. — The yellow spot is a minute area of the retina that is in direct line from the pupil. The nerve endings in this area are of such a character that vision is clearest at this point (Fig. 194).

The Blind Spot. — Light falling on the optic nerve itself does not give the sensation of light, but gives it only when falling upon the ends of the nerve fibers. Where the optic nerve enters the eyeball, there are none of these endings, and the light that falls there does not enable us to see anything. In the following experiment shut the right eye, and be careful not to let the eye waver: * Read this line slowly. Can you see the star all the time? If not, change the dis-

tance to the book and read the line again. In the human eye the optic nerve enters not in the center, but at a point toward the other eye. The optic nerve along its course is not sensible to light, but if it is cut, it gives the sensation of a flashlight. This shows that the nerve, when stimulated, responds by transmitting the kind of impulse that is associated with its function.

The act of accommodation. — Hold a pencil or finger in line with some object, as a picture on the wall. When looking at the finger, the picture is blurred and vice versa.

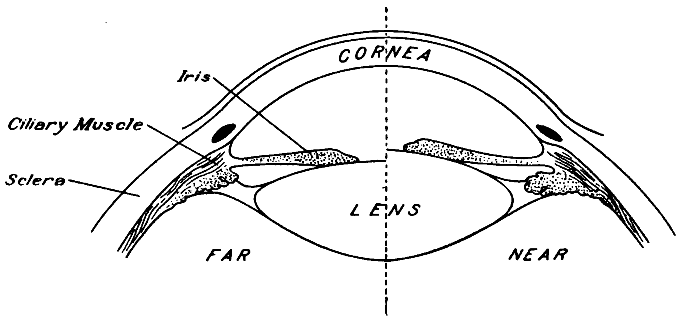
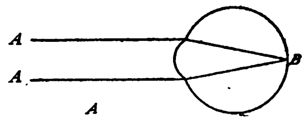


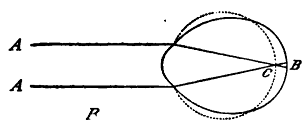
Fig. 195. — Diagram to illustrate accommodation.

When looking up from a book that we are reading, to a distant object, we do not realize that any change in the eye is necessary; but the lens changes in shape, becoming more flattened for the more distant object, and becoming thicker again when a near object is looked at, thus always bringing the rays to a focus upon the retina at whatever distance the object may be (Fig. 195). But the power fails at a point called the near point, about four inches from the eye for most persons, and the image becomes indistinct. The change in shape of the lens is called accommodation; it is brought about by means of the muscular fibers around the lens. Straining of the muscles is required for looking at very near objects.

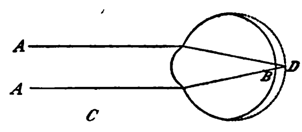
Regulation by the iris of the amount of light admitted. — Look toward a bright window or the sky and note by means of a hand mirror the size of the pupil. Turn at right angles to the light, still looking in the mirror, and note the size of the pupils. What have you noticed about the eyes of a cat at night or in the darkened room? How do your own eyes feel when going from the dark into a lighted room? Can you see as well when you first go from a brightly lighted room into a dimly lighted one, as after being in the dim light for a short time? The iris contains circular muscle fibers, which reduce the size of the pupil, and radiating fibers, which enlarge the pupil. The arrangement of pigment sometimes follows the line of the fibers. Have you ever noticed lines in the iris?



Normal eye, in which parallel rays of light (*A*, *A*) focus the image on the retina at *B*.



Myopic, or nearsighted eye, in which parallel rays of light (*A*, *A*) focus the image in front of the retina at *C*, producing a blurred image on the retina at *B*, the rays diverging from *C*.



Hypermetropic, or farsighted, eye, in which parallel rays of light (*A*, *A*) are focused behind the retina at *D*, producing a blurred image at *B*.

FIG. 196.

Did you ever whirl a stick with a glowing coal on its end? What was noticed? Can you notice anything similar if you shake the hand up and down quickly before the face? If you gaze for a moment at a bright light, then quickly close the eyes, what is noticed after the eyes are closed? These effects, called after-images,* are produced by the action of light upon the pigment of the retina, an effect which persists for a fraction of a second after the light is removed.

Defects of vision (Figs. 196, 198). — In near-sighted eyes the eye is too long from front to back, and the rays come to a

focus before reaching the retina. Among savage nations, where no books are used, almost every one has good sight, and nearsightedness is hardly known. Nearsightedness may be inherited or may begin with children at school. Some children seem to have a natural wish to get their eyes close to the book or writing. This is very undesirable for nearsighted persons. The head should be held erect in reading, to prevent blood congesting in the eyes, and to prevent round shoulders and flat chest. The proper distance for reading is fourteen to eighteen inches. The farsightedness that occurs in youth is caused by the eyeball being too flat. In the farsightedness of old age the lens has also lost its elasticity, so that its shape cannot be sufficiently changed to bring the lights from near objects to a focus on the retina. In farsightedness, convex glasses are used, and in nearsightedness, concave glasses are used. Astigmatism * is a defect caused by unequal curvature of the cornea in different directions.

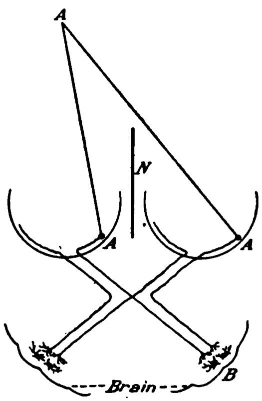


FIG. 197. — Diagram of the course of the retinal nerve fibers. Light from *A* strikes the outer part of the right, and the inner part of the left, retina. The fibers from these parts go to the right half of the brain, *B*. *N* represents the nose. The spots *A* and *A* on the retinæ are habitually stimulated together.

Care of the eyes. — Sight is priceless. (When reading is mentioned in these suggestions, it is meant to include such work as writing, sewing, embroidering, etc.)

1. *It is important to have proper light.* The light should be steady, not flickering; we should not read after sunset by the fading twilight; we should not read with the sunlight falling on the book; we should not read facing a window or with a light directly in front, unless the eyes are protected

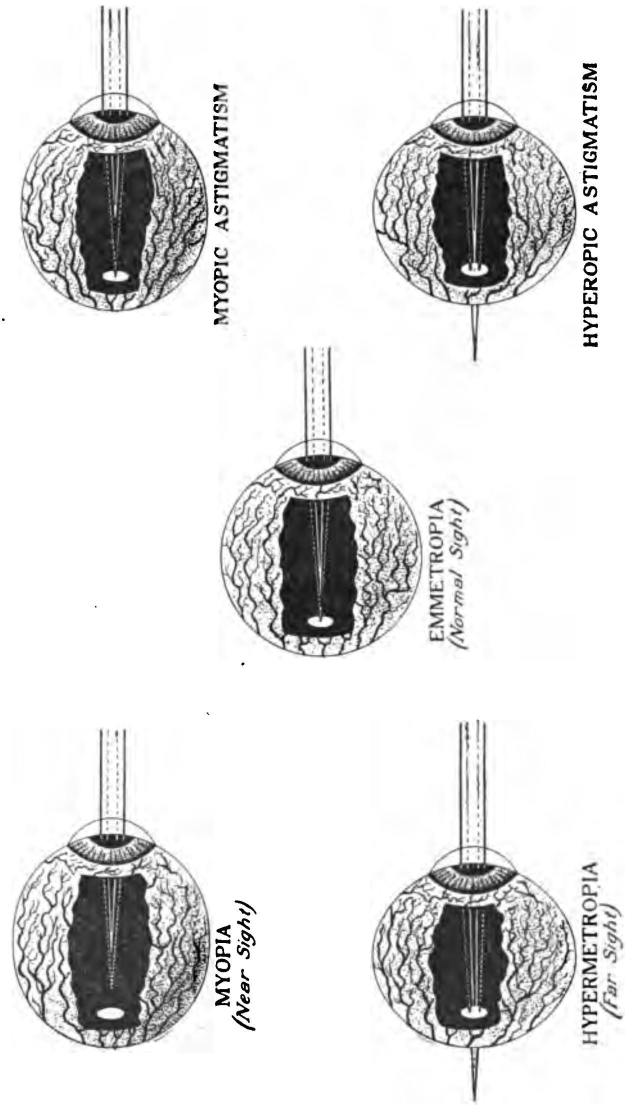


FIG. 198. — Diagram of defects of eyesight. In astigmatism the rays from one right angle plane focus on the retina but the rays from the other fall in front of (myopic) or beyond (hyperopic) the retina.

by a shade. The best artificial light is that given in the indirect or semi-indirect * method of illumination, either by gas or electricity (Fig. 199). In such lighting there is no glare. Is there glare on the blackboard in your room?

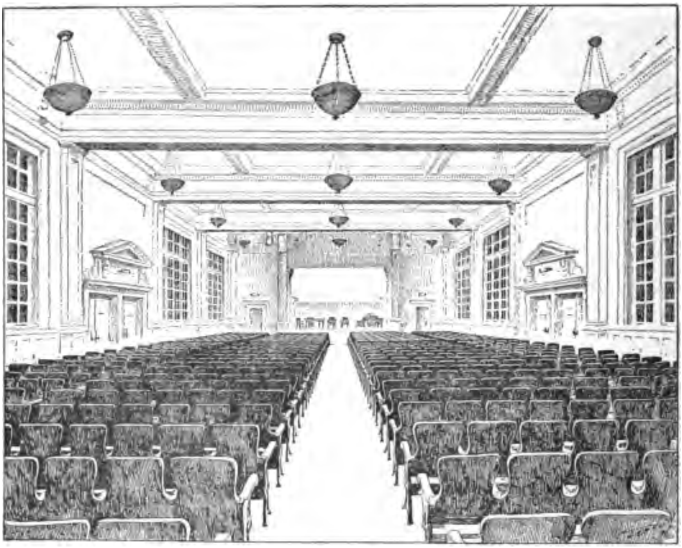


FIG. 199. — Indirect lighting without glare.

This means that the windows are not placed properly. Light curtains diffuse the light evenly, but dark curtains cause lights and shadows.

2. *The state of the eyes is of importance.* We should not read when tired or sleepy; when convalescing from an illness; with the head bent down; when the eyes are sore; when they are tired, unless we rest them every few minutes by looking at far objects; when riding in jolting cars and carriages; when the circulation is impeded by tight clothing around the neck.

"Tobacco blindness" sometimes results from smoking.

The first symptom is color blindness, which is followed by haziness of vision, and finally, by partial or complete loss of sight.

3. *The character of the object of vision is of importance.* The type from which books are printed should be large. The paper should not be pure white or glazed, but a neutral tint; it should be opaque, so that the printing will not show through from the reverse page; the lines should not be more than four and a half inches long. Publishers of magazines are the worst offenders in using shiny glazed paper because it brings out the beauty of fine engravings.

The sense of hearing. — The ear brings to the auditory area of the brain sensations derived from sound. These sensations are received and transmitted by the auditory nerve. For the purpose of receiving it has a special sense organ, the ear.

Structure and function of the ear. — The ear may be described in three parts, the outer, middle, and inner ear

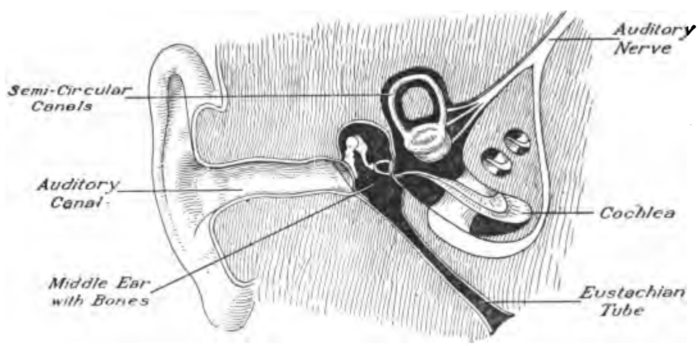


FIG. 200. — Diagram of ear and Eustachian tube.

(Fig. 200). The outer ear consists of the cartilaginous concha, the part that is usually spoken of as the "ear," and the meatus, the canal leading into the head from the lower part of the concha. Which part of the concha is not

cartilaginous but fatty tissue? Part of the wall of the meatus is of cartilage, but the deeper part has a wall of bone. The entrance of the meatus is guarded by hairs, and its wall is covered with a bitter wax secreted by glands in the lining. Its inner end is closed by the tympanic membrane, which is sometimes called the drum, but it is only a drum skin. Three little bones stretch across the true drum, which is the middle ear, to a small film separating the middle ear from the internal ear. These three little bones are called the hammer, anvil, and stirrup. The middle ear communicates with the pharynx by a narrow tube called the Eustachian tube. This tube is for the purpose of admitting air to the middle ear, so as to equalize the air pressure on each side of the membrane and prevent straining it. Sometimes blowing the nose may press the air up into the middle ear and press the walls of the Eustachian tube together and close it. This causes slight deafness for the time. The pressure may be relieved by holding the nose closed and swallowing, thus opening the passage to the middle ear. One end of the hammer is attached to the inner surface of the drum skin; the other end is attached to the anvil; and one prong of the anvil is attached to the stirrup, which in turn is fastened by base to the small film stretched across the round hole in the bone, opening into the inner ear, or labyrinth. The inner ear consists of several cavities containing a liquid in which rest the endings of the auditory nerve. The endings of the nerve are elaborated into an organ, the cochlea, for receiving sound waves and three semi-circular canals which are concerned in equilibrium.*

Sound waves, entering by the meatus, set the drum skin to shaking; the vibrations are conveyed by the chain of bones (Fig. 201) across the middle ear to the liquid of the inner ear. The wave travels through air in the outer ear, solids in the middle ear, and liquids in the inner ear. The vibrations of the liquid, in the cochlea, start nerve impulses

in the fibers of the auditory nerve, and when these impulses are received and interpreted in the brain, the miracle of the conversion of the external sound wave into the sensation of sound is complete.

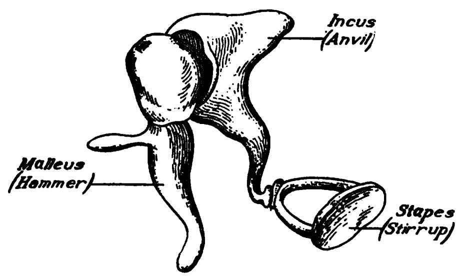


FIG. 201. — Bones of right ear, enlarged; malleus, incus, and stapes.

It is now believed that the semi-circular canals (Fig. 202) of the inner ear are not concerned in hearing. The weight of the liquid they contain pressing upon the nerve fibers located in them and exerting a varying pressure according to the position of the body, gives us the "equilibrium sense," which enables us to know the position of the body at all times, that we may preserve its equilibrium. Sight and the muscular sense also contribute to maintain the equilibrium.

Care of the ear. — The meatus is self-cleansing; the wax changes into dry scales, which fall out. The external ear should be washed, but when we reach the passage, we should go no deeper than we can easily reach with the tip of the finger covered with a damp cloth; especially the finger should not be forced into the tender ears of children. A blow with the flat hand upon the ear may force the air in and injure the tympanum. Picking the ear with hard or sharp objects is dangerous to the tympanum.

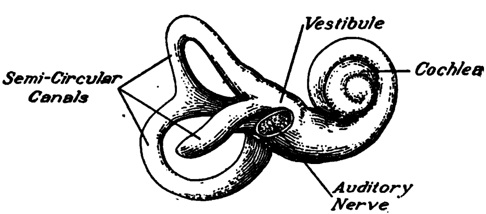


FIG. 202. — The inner ear, or labyrinth.

Sometimes the wax collects in a lump near the drum, causing deafness. The remedy is to syringe the meatus with warm water until the lump is softened and comes away. The bitter wax is a protection against insects. Quinine often interferes for a time with the hearing. Chronic cold in the throat reaching the ear through the Eustachian tube sometimes injures the hearing.

The sense of touch. — The four special senses of sight, sound, smell, and taste are located in special organs. Touch is located in all parts of the body. When an object touches the skin, an impulse is taken to the brain. There it gives rise to a sensation of touch (Fig. 203), composed of temperature (warmth or cold), pain, or pressure. Three kinds of sensations are thus included in the general name of touch. Touch strictly gives only such ideas as those of size, shape, location, smoothness, hardness, and dampness. The ends of the fingers can distinguish two points as separate points if they are only $\frac{1}{12}$ of an inch apart, while if the two points are applied to the back, they feel as if they were one point until they are separated two inches.

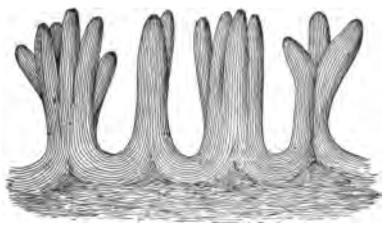


FIG. 203. — Four papillæ of the true skin, magnified. The epidermis has been removed. Most papillæ contain touch corpuscles.

The covering of epidermis not only protects the nerves and the other delicate organs in the true skin, from injury, but also modifies any impression, so that in producing a sensation it is spread over several nerve endings instead of one, and is thus turned into a gentle instead of a painful sensation.

Temperature. — Temperature may give warmth or cold sensations. This part of the sense of touch is located only

in certain points or spots, called heat spots and cold spots, situated a small fraction of an inch apart (Fig. 204). Some spots give a sensation of heat only, and some of cold only. The sense is so delicate that a difference of $\frac{1}{8}$ of a degree of temperature between two objects can be detected. Extremely hot and cold objects injure the cells and do not give sensations of temperature but only of pain.

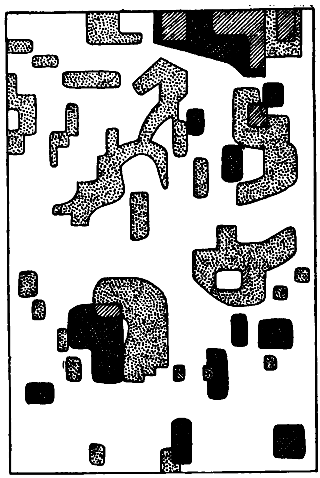


FIG. 204. — Cutaneous "cold" spots (light shading) and "hot" spots (dark shading); anterior surface of the thigh.

Pain. — A sensation greatly increased or often repeated becomes unpleasant and is called pain. The same physical influence may be felt at one time as a pleasant touch, and at another time as a pain, depending upon the state of the nerve tissue. When an influence is becoming strong enough to endanger the body, the simple sensation of touch becomes changed into one of pain and warns us to avoid the danger. When a nerve is laid bare and touched, or cut midway in its course, the feeling is not one of touch, but of pain. Pain is a protection, and therefore more of a good than an evil. In many diseases it is a prominent symptom, and the physician is begged to give relief. But the wise physician hesitates before giving morphine or other sedatives, knowing that to drown the pain is to conceal the danger, and take away his best evidence as to the state of this disease. At the same time, he runs a risk of starting a habit in the patient of deadening pain and hiding unpleasant feelings by taking narcotics, a habit that may become fastened upon the

patient and ruin his life. Hence when sick we should bear pain bravely.

Usually pain arising from the skin is located definitely by the nervous system and the place is easily recognized. Pain arising from an internal organ is located very inaccurately. For example, the pain from a severe toothache may be felt quite generally over the side of the face. Often the pain from an internal organ is felt in a definite skin area and so cutaneous pain in certain places refers to trouble in certain internal organs. For example, pains arising from the stomach are located in the skin at the tip of the sternum; pains from the heart in the region of the scapula.

Pressure. — The sense of pressure is a part of the touch complex. The pressure points in the skin are more numerous than the temperature points and in the parts of the body supplied by hairs these pressure points lie over the hair follicles. This explains the delicate mechanism provided in animals which can feel their way in the dark by the long hairs of the face. What animals show such provision? It has been found that after anesthetization of an area of the skin, there remains a deep or subcutaneous sensibility to pressure and movement. The nerves that enable us to distinguish lighter pressures are associated with the recognition of temperatures.

The muscular sense. — When an object is lifted, it is felt to be distinctly heavier if its weight is increased by only $\frac{1}{17}$, but when it is laid upon the skin, its weight must be increased by $\frac{1}{3}$ before it feels heavier. Hence it is concluded that sensations of weight and resistance to the muscles depend upon the amount of muscular effort needed to overcome the resistance as well as upon the feelings of pressure upon the skin and body. Close your eyes and place the index finger of your right hand on your left eye. Are you able to do this? Sensations coming from the muscles of your arm, from the tissues of the joints of the arm, go to the

brain and tell how to direct the hand. This sense is called the muscle sense. It is of great service in maintaining the balance in walking and in making coördinations.

General sensations of the body. — We have besides the special senses, the general sensations of hunger and thirst. These two bodily sensations arise from conditions within the body due to the chemical reactions or water content of the tissues.

Hunger. — The sensation of hunger is due to the contractions of the empty stomach. It has been stated in the past that hunger was due to a general need of the body for food, but the sensation passes away long before there is time for digestion and absorption to occur. In addition, hunger may be appeased by taking only a small amount of food. That contraction of the empty stomach produces the sensation of hunger has been experimentally demonstrated by Dr. Cannon of Harvard, and others have seen by an opening in the abdomen so that the stomach could be observed, that the stomach is contracted during the time that the sensation of hunger persists. Eating between meals keeps the stomach working so that at mealtime it is not contracted and ready to digest the food. This is an important reason for not eating between meals. The contracted state is an expression of its readiness to receive food and care should be taken, therefore, not to have habits that produce a relaxed stomach.

Thirst. — The sensation of thirst is felt in the pharynx and the nerves in this region have the power of giving this sensation. It has been learned that the cells of the body are made of protoplasm and that this protoplasm is liquid. We also remember that the cells are bathed in lymph. The fluid content of the body in health remains nearly constant. When we sweat, water is lost and we replenish that removed by drinking more water. When the water content falls below a certain point the nerves in the mucous membrane

of the pharynx are stimulated by the blood, which has lost the water. This gives us the sensation of thirst.

APPLIED PHYSIOLOGY

LABORATORY EXERCISES

Experiment 1. To study the sense of sight.

Material. — Snellen Test Chart (Plate X, back inside cover), and figure for testing astigmatism (Fig. 205).

Method and Observation. — Place the Snellen chart a distance of 20 feet from the observer. Have it placed at the level of the eyes and in good light. The distance 20 feet is chosen, because at that distance light comes into the eyes in parallel rays.

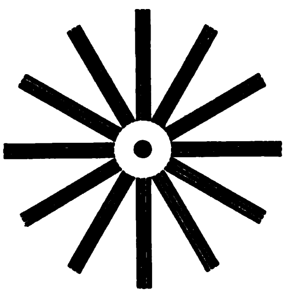


FIG. 205. — Test for astigmatism. Reading distance. If this defect exists, the lines that run in one direction will appear more distinct than the lines in other directions.

Hold a book in front of one eye and have the observer read the line marked 20 feet. If he can read the letters correctly, the vision in that eye is normal. If he can read only the "40 feet" line, the vision is ½.

Test the other eye in similar fashion.

The test for astigmatism is made by seeing at 20 feet if all the lines of the chart (Fig. 205) are of equal width. Some of the lines may appear heavier or more distinct than others.

Experiment 2. — To study the sense of hearing.

Method and Observation. — At a distance of 20 feet have the observer stand with one hand over one ear. At that distance, whisper in a low voice and test whether or not the observer hears and understands. The whispered voice will be heard at 20 feet by the normal ear.

In similar fashion, test the other ear.

Experiment 3. To test color blindness.

Material. — A set of standard color worsteds with their tints and shades.

Method and Observation. — Test the student with the different colors and note the difference in accuracy.

Experiment 4. To analyze sunlight.

Material. — Prism.

Method and Observation. — Throw the rays of the sun after passing through the prism upon a sheet of paper. Note what colors are present in the spectrum.

Experiment 5. To test sharpness of vision.

Material. — White thread and black card.

Method and Observation. — Cover one eye and measure the greatest distance at which the thread can be seen on the card. Test each eye. Test both eyes.

Determine the greatest distance when the card is placed 30 and 60 degrees from the line of vision.

Experiment 6. To test change in iris.

Material. — Two persons.

Method and Observation. — Place subject facing window. Cover one eye and on raising the hand, note the change in size of the pupil.

Compare size of pupil when looking at near and at distant objects.

Experiment 7. To test the dermal senses. (Fig. 204.)

Material. — Drawing compass, scale graduated to millimeters, fine horsehair, pencil, forceps, vessels of cold, lukewarm, and hot water.

Method and Observation. — (1) Place a straight piece of horsehair in forceps and determine the greatest length that will give sensation of pressure. Then test the relative sensitiveness of the palm and back of the hand, the cheek and lips, forearm and forehead.

(2) Determine the least that the points of the compass may be separated and still be recognized as two points, when placed in contact with the parts given in (1).

(3) Make slight pressure on the back of the hand with pencil and determine the sensations that arise.

(4) Put finger of right hand into a vessel of warm water and finger of left hand into a vessel of cold water. Notice the kind of sensations that come from the two fingers. Does this sensation change while the fingers are kept in the water?

Withdraw both fingers and place them at once into a vessel of lukewarm water. What are the sensations experienced now?

Experiment 8. To test the sense of taste.

Material. — Salt, sugar, vinegar, quinine.

Method and Observation. — Test with the different substances the tip, the sides, the back of the dry tongue and determine where the sense of taste for the different substances is located.

GLOSSARY

After-image. — The sensation of an object after the object ceases to be present.

Aqueous humor. — The water-like liquid in the front chamber of the eyeball.

Astigmatism. — A condition of sight in which the light rays which come into the eye on the horizontal plane of the eyeball come to a different focus than the rays that come in over the vertical plane. It is due to a difference in the curvature of the surface of the cornea.

Choroid. — The middle layer of the eyeball. In this layer are the blood vessels that supply the eye.

Convex-lens. — A lens that is curved like the surface of a sphere.

Crystalline. — Like a crystal, transparent, clear.

Dispensary. — An institution at which sickness is treated and medicines given.

Equilibrium. — A state of control of the body; balance.

Image. — A visible representation of a thing.

Lens. — A structure capable of directing rays of light. This may be reflection to bring them to a point (as a sun mirror) or to scatter them.

Perception. — Understanding of the sensation that is received.

Pupil. — The opening in the center of the eye caused by the arrangement of the iris muscle. This muscle has a circular and radial arrangement and can constrict or dilate the pupil.

Retina. — The innermost layer of the eyeball. It is formed by the branching endings of the optic nerve.

Sclera. — The outermost layer of the eyeball. It is formed of connective tissue and provides the eye with a firm capsule.

Semi-indirect. — A variety of illumination. In this variety the light units are suspended in a bowl-shaped structure from the ceiling and rays of light are reflected downward from the ceiling and also pass directly through the bowl.

Sensation. — A conscious state resulting from a stimulus.

Stereoscope. — An optical instrument for blending into one image two pictures of an object.

Trachoma. — A very contagious disease of the eye. It is commonly called " sore eyes."

Vitreous humor. — The glass-like liquid in the back chamber of the eyeball.

CHAPTER XVIII

SOME SPECIAL REGULATIVE PROCESSES

I. The Regulation of the Temperature of the Body.
II. The Regulation of Body Activity and Growth.
  Thyroid secretion
  Thymus secretion
  Adrenal secretion
  Pituitary secretion
  Pancreatic secretion
III. The Control of the Voice.
  The breath
  The larynx
  The resonant chambers
  Pitch, volume, and quality
  The care and culture of the voice

The regulation of the temperature of the body. — Man lives in the torrid zone and in the frigid zone, yet his temperature remains the same as he goes from one zone to another, and as summer changes to winter. The temperature of the healthy body is about 98.6° F. This is unmistakable evidence that some means of maintaining a uniform temperature exists in his body. This means for regulation of heat works in two ways. The body controls its loss of heat as well as its production of heat and under normal conditions both means are used. Heat is lost from the body in the following ways:

1. Through the excreta and waste of the body.
2. Through the expired air. This air is warmer than the inspired air.

3. By the evaporation of moisture from the skin. This heat loss is increased with the increase of perspiration.

4. By conduction and radiation of heat from the skin.

We can to some extent control this heat loss through evaporation and radiation by wearing appropriate clothing. In winter the clothing should be chosen to diminish this heat loss and the material usually selected is wool. There is also automatic control of the heat loss by reflex control of the sweat nerves and the nerves to the blood vessels (vasomotor nerves). These vasomotor nerves are apparently under the guidance of a special center, so that a greater or less amount of blood, as desired, may be sent to the skin. On warm days the skin vessels are dilated; on cold days they are contracted.

Heat is produced in the body by oxidation of food materials. The body burns its food and so forms heat, and an increase in good food gives more material for heat. Why do we eat more in cold weather? This heat production is regulated by the heat center or other controlling centers acting through the nerves going to the muscles. It is also regulated by the quantity and character of the food eaten and this is determined by the appetite. Body heat, therefore, in its production and in its loss is cared for by the body. By an understanding of the physiology of the process, we may so act as to assist the body. If we act contrary to the body laws, we are working against the body. Write down in two columns the ways in which the body may be assisted in heat production and in heat loss.

The regulation of body activity and growth. — It has been learned that there are secretions which empty into the alimentary canal through ducts leading from the secretory glands. Now there are other glands which produce secretions which they give directly to the blood stream and such are called internal secretions. They are discussed under the chapter on special regulative processes because they in-

fluence the activity of organs through the body; in addition, some are concerned in the phenomena of growth and development. If you have ever seen a cretin,* you have seen a person who lacks one of these internal secretions, that from the thyroid gland, situated in the neck. These secretions are called hormones (from ὁρμάω, *arouse or excite*).

Thyroid secretion. — The thyroid is a gland lying in the middle line of the neck and just below the thyroid cartilage. This secretion is necessary for proper physical and mental growth.

Thymus secretion. — The thymus is a gland that develops until the age of 12–13 and then decreases in size. It lies just above the heart. This gland gives an internal secretion that is of great importance in the development of the child.

Adrenal secretion. — The adrenals are small glands lying on top of the kidneys. These glands give in their secretion a substance, epinephrin, which acts as a stimulant to the heart and blood vessels and serves to increase the blood pressure. This gland becomes very active under emotional conditions. The power that one has when stimulated by fear or excitement to do a tremendous physical feat is given by the epinephrin from the adrenals.

Pituitary secretion. — At the base of the brain, lies a little gland, the pituitary gland. This gland has two lobes, an interior (front) and a posterior (back). The posterior lobe furnishes a secretion which causes a rise in blood pressure and slowing of the heart beat. The anterior lobe apparently gives a secretion of importance in the growth of the body and especially in the growth of bones. Increased activity of this lobe of the gland is responsible for giantism.*

Pancreatic secretion. — The pancreas gives a duct secretion. What are its enzymes? It also gives a hormone directly into the blood and this hormone is concerned in the oxidation of sugar in the body. Disturbance of this secretion, produces the disease known as diabetes.

It will be noticed, therefore, that the human body is very complex in its regulation and control. Unseen forces are at work directing its growth and controlling its development. It is a mistake to believe that body health and vigor may be obtained by the performance of formal gymnastic exercise in the home or gymnasium. This human body must be used with reference to its controlling mechanisms and its evolutionary development. If man will use his body in natural and wholesome ways of exercising it, eschewing alcohol and tobacco, selecting good foods and pure water, and obtaining fresh air and clean surroundings, then weakness and disease will not be so common. The body in this way will serve, as it should, as a fine and splendid temple for the soul and the soul will be enriched.

The control of the voice. — Man conveyed ideas in primitive times before the use of the voice, by gestures. To-day this is called pantomime and as a means of conveying ideas it is less necessary because man has the ability to express his wants and desires by the spoken word. The voice, therefore, is the means of communication between individuals; it is not the only means, however, nor should it be used alone because the use of the muscles of the body in producing movement and different forms of expression makes clearer and more forceful the meaning of the thought conveyed by the voice. The voice is used to convey ideas in song, and this use is not only utilitarian but also may be such as to give pleasure. Now whether the word is spoken or sung there are certain important facts in the production of this sound that are to be considered. The first of these is the breath by which the sound is produced, the second is the larynx in which the sound is produced, and the third is the resonating chambers which modify and mold the sound. The voice may be likened to a musical instrument in which the breath is the motive factor, the larynx is the string in the case of a violin, and the resonators are curves and flut-

ings of the horn. In certain respects the voice resembles more a violin and in others it may be likened to a horn.

It is very important that the child learn to use the voice properly and to this end there should be instruction in speaking and singing.

The motor factor — breath. — For the production of sound, air must be taken into the lungs and while under control it is allowed to pass out over the strings in the larynx, thus producing sound. In the chapter on respiration it was learned that there were three ways of breathing: costal, abdominal, and natural. Now, inasmuch as the diaphragm is so important in supporting the sound produced you have another reason why breathing should combine abdominal and costal. This form of breathing will give more air and at the same time will have it under better control. It is very important that the parts of the body be adjusted in the proper way and in this connection is it important to remember the correct standing position. How often have you seen girls and boys who were unable to speak plainly? Did you notice that their standing position was very poor? One who wishes to have a good voice must learn to stand in a position that will allow the chest to have free and unobstructed movement and that will keep the abdomen well drawn in. As a result, the larynx will be supported in the proper place in the throat.

The vocal instrument — the larynx. — The larynx, in which the voice originates, is a cartilaginous box with three sides, the sharpest corner forming a ridge in front (Fig. 206). In many persons the larynx is prominent in the neck, and is called the Adam's apple. The lid of the voice-box, or larynx, is also of cartilage, and is called the epiglottis. Across the middle of the box are stretched two bands, or half curtains, called the vocal cords (Fig. 207). Their ends are attached to the front and back of the larynx. They are not true cords, however, as they are thin and flat, and one

edge of each band is attached to the side of the larynx. Since the cords run across the middle of the chamber from front to back, the free edges are brought near together. The slit, or opening between these edges, is called the glottis. During ordinary respiration the cords are relaxed and the slit is wide open. To make the voice, the vocal cords must be brought very near together and drawn tight, and a current of air must be forced through the narrow slit to throw the cords into vibration. The front ends of the cords are attached to the larynx just within the angle, or ridge, called the Adam's apple. The rear ends are attached to two little movable cartilages at the back of

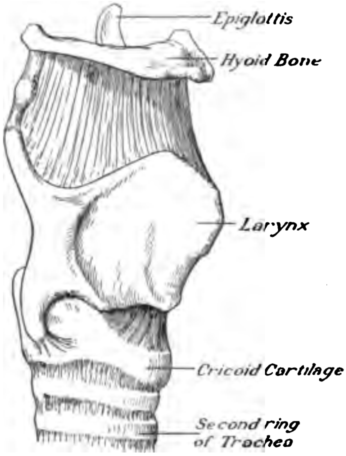


FIG. 206. — View of the right side of the larynx, from the front.

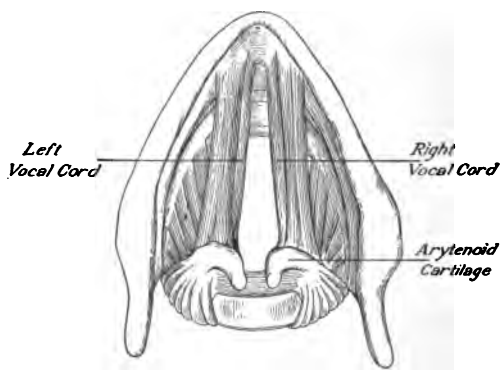


FIG. 207. — Cross-section of the larynx above the vocal cords, with the mucous membrane removed.

the chamber. The moving of these little cartilages by the muscles of the larynx brings the edges together and tightens the cords.

Sound waves, or sound vibrations, are imparted to the air by the tremulous motion of the cords. The limits of the vibrations which the human voice is capable of making are from 42 vibrations per second for the lowest tone, to over 2000 vibrations per second for the highest tone. Lower C of the soprano is produced by 256 vibrations per second. The limits of vibrations which the human ear is capable of hearing are from 16 to 50,000 vibrations per second, but until they reach a rate of about 50, the sound is more like a buzz than a tone. Some people cannot hear the voice of mice, or the squeak of a bat, because the high pitch is beyond the limit of their hearing.

The resonant chambers. — The vibration of the vocal cords alone produces a weak, squeaky sound, but their vi-

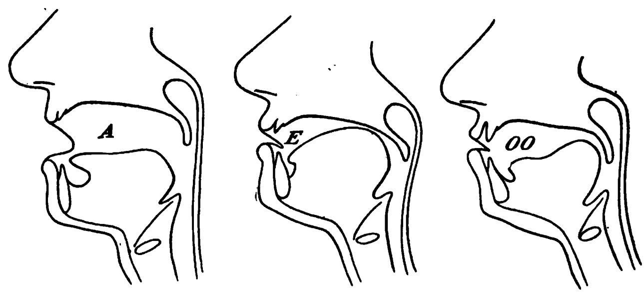


FIG. 208. — The shape of the mouth in sounding the vowels *a, e, oo.*

brations are reënforced or strengthened by the vibration of the walls of the lungs and trachea below, and of the nose and mouth above (Fig. 208). These echoes, combining with and reënforcing the vibration of the cords, determine the quality of the voice. Just as the shape and material of the walls of the violin give the quality to its tone, so the shape and condition of the nasal passages, throat, etc., give

characteristic quality to each human voice (Fig. 209). If the nasal passages are stopped up by catarrh, the person is said to speak in a nasal tone, or through the nose, but a "nasal" tone really results only when the sound cannot come through the nose. Such a person's voice does not change its quality when he speaks with his nose stopped with his fingers. But a voice which has correct nasal resonance * will change its quality when the nostrils are held. Try it, and see whether your voice retains its nasal resonance. Let one pupil read aloud at the back of the room where the

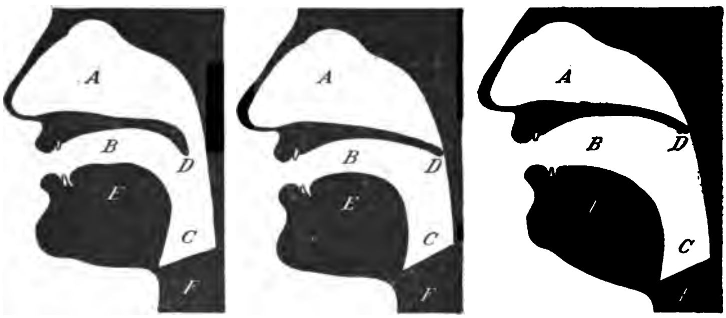


FIG. 209. — The resonant chambers. *A*, resonance cavity of the nose; *B*, resonance cavity of the mouth; *C*, resonance cavity of the pharynx; *D*, soft palate; *E*, tongue; *F*, point at which vibration begins.

The figure on the left shows soft palate (*D*) in normal position, allowing air in naso-pharynx to vibrate in unison with initial note. The middle figure shows soft palate raised, shutting off the resonance and rendering tone thin and hard. The figure on the right shows another common fault. The tongue is lowered, increasing the size of the mouth cavity. This increases the volume of the tone, but renders the quality harsh and hollow (Latson).

others do not see him, and find whether they can tell, by the change in his voice, at which word he closes his nostrils in the midst of the reading. The vocal cords are not used at all in whispering. It is akin to whistling. In singing, single sounds are more or less prolonged. In speech, the principal changes are in the duration of the sound, and in the resonance in the mouth. In whispering, audible breathing is cut

off by the tongue and lips, and words are articulated, although no sound comes from the vocal cords. A public speaker ordinarily utters 125 words per minute. If there are four sounds to a word, this amounts to 500 sounds each minute or eight each second.

Pitch, volume, and quality. — The rate of vibration of a cord, and hence the pitch of a sound, are influenced in several ways. Is the string of a violin or of a guitar tuned up or down by tightening it? Which is higher in pitch, a long or short string of a harp or a piano? Which makes a higher note, the light or the heavy string of a violin or a guitar? The pitch of the note given by a string may be raised in three ways: tightening, shortening, or decreasing the weight of the string. From these facts explain why the voice rises in pitch when we are excited, the muscles at that time being contracted with greater force. Why does a cold with congestion of the cords cause a person to speak in a hoarse, deep voice? Why does a man, whose larynx is larger than a woman's, have the deeper voice? Why does a boy's voice change as his larynx enlarges?

A man's voice has usually a pitch of one octave* below that of a woman or a boy. The range of the human voice is about two octaves. The voice may also vary in volume, or loudness, as well as in pitch. How do we speak loudly at one time and softly at another? If a tin pan is struck gently, the sound is weak; if it is struck with force, the sound is louder. We make the voice louder by stronger expiration of the breath, thus sending the air with more strength against the tightened vocal cords. Two persons sing a song together in the same pitch and with the same loudness; yet you can readily distinguish a difference in the two voices. This is because of a difference in quality, which is the third variation possible in a voice. Sound in wind instruments is strengthened by resonance, which is a kind of instantaneous echo in the pipes.

The care and culture of the voice. — The voice should not be used more than is absolutely necessary when it is hoarse. Catarrh may injure the voice by injury to the vocal cords or by obstruction of the nasal passages.

The best way for a child to acquire distinct and refined speech, is to hear it habitually. Great numbers of people are handicapped by hasty, harsh, indistinct, or disagreeable speech. Parents and teachers should remember as children are growing up, what an advantage to them in after life a refined, melodious voice will be. Nearly all children have sweet voices when young, but many lose them before adult life on account of acquired nervous habits, dusty and ill-ventilated rooms, deformity of lungs due to restrictive clothing, or from singing during the time their voices are changing or attempting tunes beyond the compass of their voices.

Smokers are frequent sufferers from affections of the throat. Smoking may produce a constant "hacking" cough. The hot, poisonous smoke, to say nothing of the poisonous vapor of nicotine, brought in contact with the vocal cords, is almost certain to produce mischief. Singers and public speakers usually have to give up the use of tobacco on this account. Cigarette smoking is especially bad for the voice, as the smoke is inhaled. The deep-toned voice of the chronic drinker may be an indication of inflammation of the larynx, a disease from which beer drinkers often suffer.

Methods of voice training vary, but it should be noted that there is no special virtue in any one system. To train the voice properly there must be considered the motor factor, the vocal instrument, and the resonant chambers. In some pupils one factor may need more emphasis than the others and the successful teacher will meet the needs of the pupil rather than pursue with every pupil a rigid system. To secure a rich, resonant, and flexible voice is the goal. Hence there must be no straining and no tense-

ness. Breathing exercises that call for a rigid over-filled chest destroy flexibility. Swedish formal gymnastics are distinctly harmful in this respect because they make the individual tense and rigid.

GLOSSARY

Cretin. — A person suffering from cretinism. This condition is caused by a deficiency in the secretion of the thyroid while the individual is a child.

Giantism. — A condition of the body in which all parts are enlarged and the person appears as a giant. This condition results from disturbed secretion of the pituitary gland.

Octave. — The interval between any note and that note that gives twice as many or half as many vibrations in a second.

Primitive. — Pertaining to the earliest times, especially before modern or ancient civilization.

Resonance. — A prolongation or reënforcement of sound by means of sympathetic vibration. The vibrations of the resonating chamber must come at the same time as the vibrations of the instrument producing the sound.

CHAPTER XIX

BACTERIA AND DISEASE

I. Injury to the Body by Forces in Its Environment.
II. Microscopic Forms of Life.
  Molds
  Yeasts
  Bacteria
  The work of these organisms
III. The Effects of Bacterial Growth in the Body.
  Ptomaines
  Toxins
IV. The Germ Theory of Disease.
V. Antitoxins and Immunity.
  Smallpox vaccination
  Typhoid vaccination
VI. Injury of the Body by Poisons in Food.
  Fish and shellfish
  Meat poisons
  Poisons in milk
VII. Injury of the Body by Physical Agents.
  Heat exhaustion
  Sunstroke
  Electricity
  Mountain sickness
  Caisson disease
VIII. Injury of the Body by Chemical Agents.
  Lead poisoning
  Other poisonous metals
IX. Diseases Caused by Mosquitoes.
  Malaria
  Yellow fever
X. Tuberculosis.
XI. Prevention of Communicable Diseases.
  Cleanliness of the mouth

Injury to the body by forces in its environment. — It is very important to remember that the human body is the kind of body it is, because of the way in which the members of the race have lived. For example, man has an alimentary canal that requires a mixed diet, partly because in the growth and development of the alimentary tract, a diet of flesh, vegetables, grains, nuts, and fruits is used. Now the body is injured if man in his foolishness tries to live only on nuts. Also the body of man has developed with reference to exercise. Man has inherited the need for exercise just as definitely as he has inherited his biped position. Therefore, the man or woman who sits in an office all day and does not participate in games or sports or gymnastics of any kind, will suffer from disturbances in the body due to the lack of physical exercise.

The body may also be injured by attacks from forces outside the body, such as bacteria. These minute microscopic animals are present in the air and water and are often found on objects of all kinds. They cause disease by obtaining an entrance into the body and growing there. As they grow they produce poisons, which passing into the blood

in the circulation, injure the body cells and in some cases kill them. Protection from such forces, therefore, will be obtained by preventing these bacteria from obtaining entrance to the body or by keeping the body so well that, if they do get in, they cannot grow and develop. Do you remember the parable of the sower? Well, bacteria are like seed. If they fall on stony ground (good, vigorous, healthy bodies) they die; if the leucocytes and protective agents in the blood are able and sufficient, they will play the part of tares and birds in destroying the bacteria; but if the bacteria come into the lazy, weak, inefficient body, they will produce many fold.

Microscopic forms of life. — As we trace back to their origins the lines of development of the animal and plant kingdoms, we find them converging to one common type, a single cell organism, so simple in construction and so unspecialized in function that it is impossible to tell whether it is plant or animal. These cells are so small that they can only be observed by means of the high power of the microscope. They are much smaller than the cells of the body. There are many different forms, but the ones important for us to know, are molds,* yeast, and bacteria.

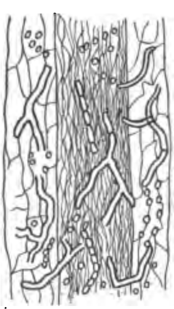


FIG. 210.—Ringworm fungus in a hair.

Molds. — Every one has seen fungus* plants, such as mushrooms and puffballs, that do not bear flowers but multiply by spores. They live upon dead logs or where there is much dead organic matter in the soil. Imagine a fungus that grows on an average about $\frac{1}{100}$ of an inch in height; this is called mold (Fig. 210). It grows, for instance, upon moist bread in warm weather. Mold forms a kind of network as it grows through any substance that will nourish it, and sends up stalks with knoblike ends, the knobs being full of minute spores.

Yeast. — Think, if you can, of small plants only about $\frac{1}{32000}$ of an inch in length, and composed usually of one oval cell, a plant that makes new plants by "budding," or the forming of a smaller cell on the old one. Yeast cakes consist of yeast plants scattered among the grains of flour of which the cake was made. Yeast plants multiply rapidly, doubling in number in two hours (Fig. 211). They grow upon sugar, decomposing it into alcohol and carbon dioxide. This process is called fermentation. In wine making, alcohol is the product sought; in bread making, carbon dioxide is the useful product, this gas giving the bread its lightness, while the small amount of alcohol formed is driven out by the heat in cooking.

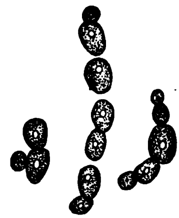


FIG. 211. — The yeast plant.

Bacteria. — But suppose the microscope shows a much smaller organism which averages $\frac{1}{200000}$ of an inch in diameter, a one-celled organism that multiplies by division like the amœba and other one-celled animals, and lives upon albuminous substances only for its food. This is a bacterium. Bacteria are called also microbes* or germs; and they are the smallest of living organisms. A bacterium that is rod-shaped is called

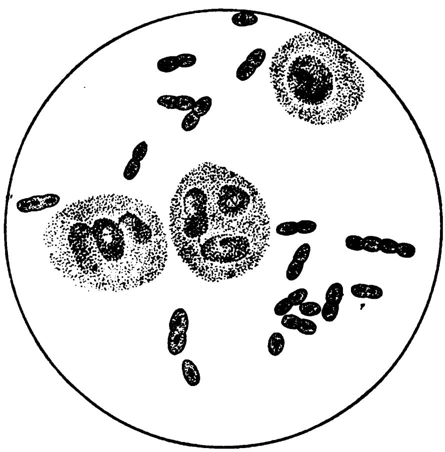


FIG. 212. — The organism that causes pneumonia is a micrococcus and is called the pneumococcus. These bacteria have a capsule surrounding the organism. The large cells are polymorphonuclear leucocytes.

a bacillus; a round-shaped bacterium is called a micrococcus; and if spiral, it is called a spirillium (Figs. 212, 213, 214). Under favorable conditions — abundance of food and considerable warmth and moisture — bacteria may double in numbers every half hour. Thus millions may result from even one in a short time. (You will comprehend this better by referring to "geometrical progression" in your arithmetic.) Dryness and cleanliness prevent their growth; cold retards their growth and division, hence the utility of ice in preserving meat, milk, fruits, and other foods in warm weather.

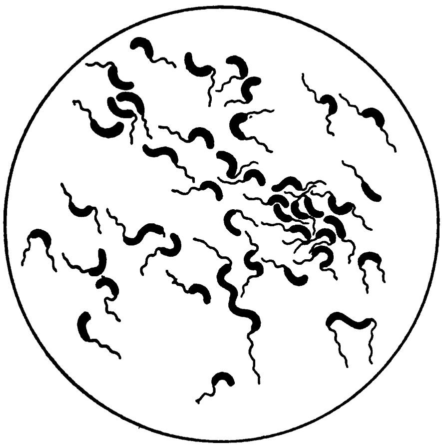


Fig. 213. — These bacteria are the cause of cholera and are called cholera spirillæ. They have small hair-like processes which serve as tails for locomotion. These are called flagellæ.

Can you now arrange the names yeast, mold, and bacterium in order of size? Can you give the kind of material that each uses for food? Can you tell how each multiplies, or reproduces its kind? What is a bacillus? For what is "microbe" another name?

The work of these organisms. — Molds are nature's tools for destroying hard and durable tissue like logs, bone, and hides, which otherwise would not decay but would fill the earth, leaving no room for living creatures. Ringworm is caused by the growth of one form of mold within the skin. It does not grow in a sound and clean skin. Falling of the hair is often accompanied by the growth of mold in the hair follicles, but it must be preceded by overheating and starving

of the cells of the scalp by a tight hat, too much brain work, or other cause. Yeast prevents the calamity of all plant food accumulating in the form of starch and sugar. Bacteria destroy the dead and excreted matter of vegetables and animals so that it melts away and is stored in the soil, ready to be utilized as plant food again. Mold, yeast, and bacteria are great blessings, for they are indispensable friends of all other living beings. They do not always wait for the dead or dying material to be excreted, or separated from the animal or plant, before attacking and destroying it. If more food is eaten than can be digested, and it remains longer than five hours in the stomach, starchy food may ferment by the action of yeast plants, giving rise to carbon dioxide gas, and albuminous food may undergo decomposition from the action of bacteria.

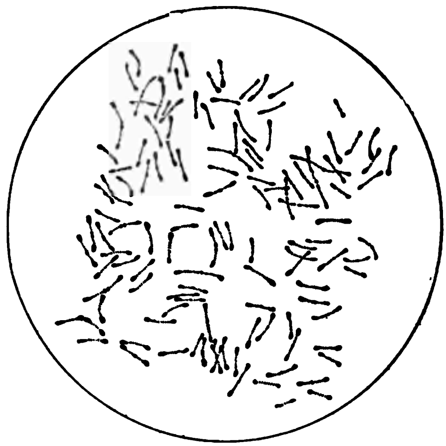


FIG. 214. — The diphtheria bacilli are the small rods shown in the picture. These organisms are killed by antitoxin given to those who have the disease.

The effects of bacterial growth in the body.—*Ptomaines.**— You learned that bacteria produce decay in unsound tissue. They destroy the albumin in which they grow, producing foul-smelling gases and a number of poisons called ptomaines, if formed after death. Ptomaines cause most of the symptoms produced by eating decayed meat. A special kind of ptomaine sometimes forms in milk and ice cream which has been kept for a long while. This is why ice cream

which has been melted, and frozen a second time, is dangerous.

*Toxins.** — The growth of bacteria in an unsound, living body, produces poisons called toxins, which, circulating among the sound tissues, produce weakness and disease. Disease germs may grow upon the injured cells in an open wound, causing offensive matter to form. Diphtheria (Fig. 214), typhoid fever (Fig. 215), tuberculosis (Fig. 225), cholera * (Fig. 213), lockjaw * (Fig. 216), and la grippe * are all diseases in which germs have been proved to be present, and all produce poisonous toxins.

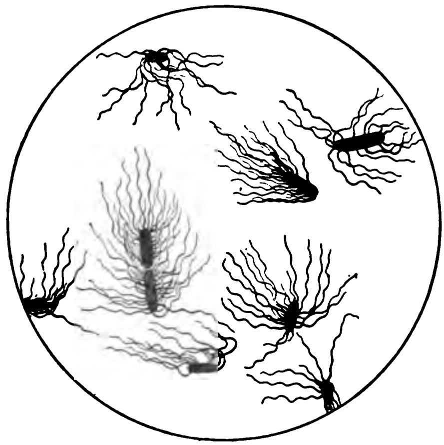


FIG. 215. — Typhoid bacilli. The growth of these organisms in the intestine produces typhoid fever.

The germ theory of disease. — Louis Pasteur, the great French scientist, made possible the modern understanding of disease and opened up the way for the treatment of many diseases that had caused scourges and plagues * in the past. Robert Koch explained and demonstrated the " germ theory of infectious diseases " mainly as follows:

1. Each infectious disease is caused by a specific germ. These germs may be found in the tissues or fluids of the body affected and the products from the growth of these germs are the poisonous agents which injure the body and give the symptoms of the disease.

The germ of diphtheria is the Diphtheria Bacillus. The

poisons from the growth of these germs in the throat give the symptoms of the disease.

2. The specific germ taken from one body and introduced into another body susceptible to the disease, will produce in the second body the same disease.

Why do we have quarantine? * In a recent epidemic of infantile paralysis in New York City, a mother fearing to take her child to a hospital left her home and traveled with the sick child to another part of the city. Why should she not have done this? Did she expose other children to the disease? Should she have been as thoughtful of other children as of her own child?

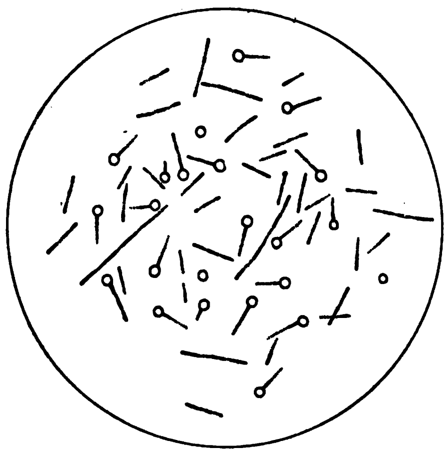


FIG. 216. — Tetanus is commonly called "lockjaw." It is caused by the bacilli shown here. The "drum stick" form is characteristic of the tetanus bacillus.

Why should we not swap apples or borrow handkerchiefs?

Antitoxins * and immunity.* — Now it is known that one attack of smallpox makes it impossible or very difficult for that individual to have the disease again. This is true in the main for all the communicable diseases. This protection against disease is called immunity, and is due to the fact that the body manufactures protective substances to kill the toxins (poisons) produced by the germs (bacteria). These protective substances are called antitoxins and the individual is said to be immune. This is an active immunity, developed by the individual himself in the course of the

disease. Now it is possible to grow these substances in another animal and then use the serum * from the blood of the animal and inject it into man. This will give him a passive immunity to the threatened disease. This procedure is used in diphtheria epidemics. Smallpox vaccination * consists in putting the smallpox virus in a small abrasion of the arm. This produces the disease in a mild form and for about seven years protects the body by the immunity conferred.

Smallpox vaccination. — In 1776, E. Jenner of Berkeley, England, learned that the milkmaids of the shire considered accidental cowpox, caught while milking, a sure preventive of smallpox. Twenty years later he began to vaccinate with cowpox material to prevent smallpox. Vaccination protects only for a few years. If exposed to smallpox, one should be vaccinated, unless he has been vaccinated within the last few years. Arm to arm vaccination is dangerous. Only fresh virus from healthy cows should be used. If the arm becomes very much swollen and disabled, it is a sign that the blood has been poisoned by the use of impure material. Some people are inclined to refuse vaccination for smallpox (Fig. 217). Their argument is that there is no danger now and they do not wish to inconvenience themselves or run even the slightest risk. This is a very selfish attitude. There is little danger to-day from smallpox, but this condition of safety has been obtained by the systematic vaccination of people. Only a selfish person would wish to derive security by the work and service of others and would refuse to contribute his share for the safety of all.

Typhoid vaccination. — Typhoid vaccination has produced remarkable results in this respect also. Years ago in war, more soldiers died from typhoid than from bullets. To-day in the armies of France, England, and Germany, typhoid is practically unknown due to the use of typhoid vaccination. Such evidence is important. The history of civilization with its plagues, its Black Death and typhoid deaths in

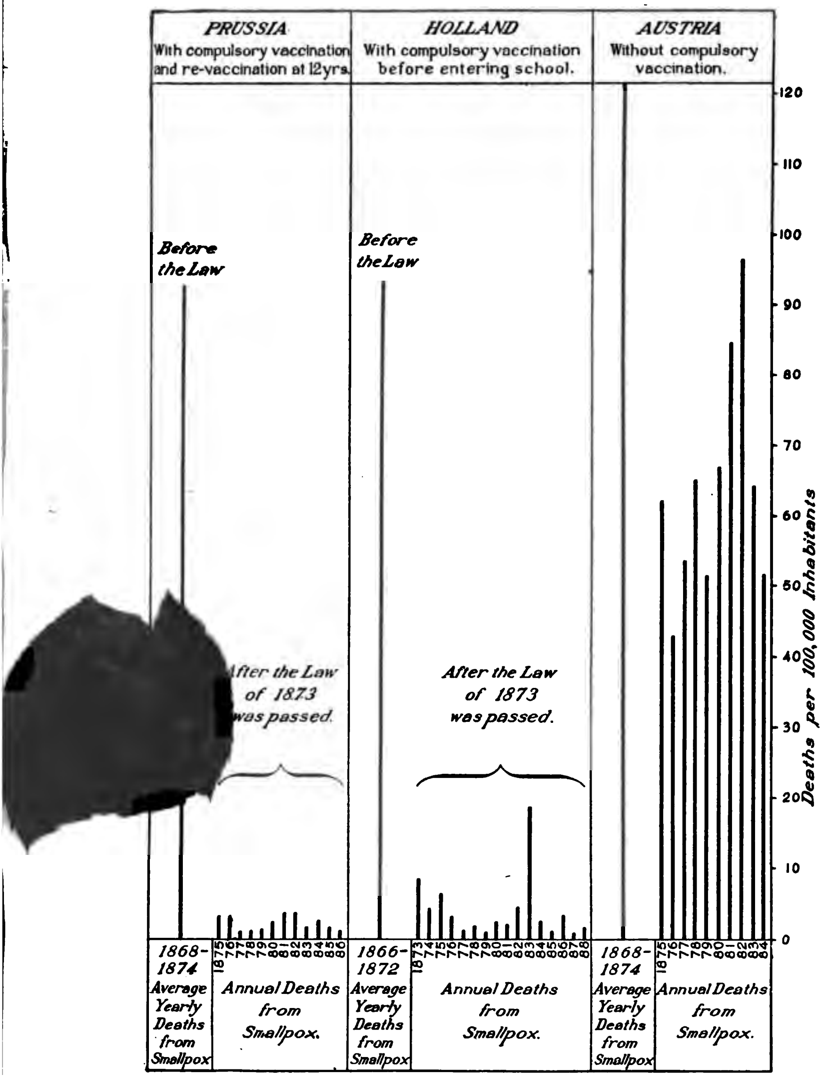


FIG. 217. — Table showing value of vaccination (Carsten).

wars proves by contrast the value of the preventive measures in use to-day.

The value of vaccination against typhoid is shown in a report of Major Lyster covering the period from 1908 to 1914.

VACCINATION AGAINST TYPHOID IN THE U. S. ARMY

YEAR	NUMBER OF PERSONS VACCINATED	NUMBER RECEIVING THREE DOSES	CASES OF TYPHOID FEVER	ARMY, MEAN STRENGTH
1908 [1]	0	0	239	74,692
1909 [1]	830	621	282	84,077
1910 [1]	16,093	11,932	198	81,434
1911 [1]	27,720	25,779	70	82,802
1912 [2]	40,057	All	27	88,478
1913 [2]	25,086	All	4	90,752
1914 [2]	35,902	All	7	92,877

Injury of the body by poisons in food. — Food that is not fresh undergoes fermentation and decomposition. In this change poisons are formed which taken into the body cause disturbances and in some cases death results.

Fish and shellfish. — Fish that is not fresh should not be eaten. The signs of freshness in a fish are firmness of the flesh, protruding eyes, red gills, and a clean fish. Mussels, oysters, and lobsters decompose rapidly and produce serious illness unless absolutely fresh.

Meat poisons. — Animals that are ill, should never be used for food. Meat that is spoiled is unwholesome and should not be eaten. Sausages and other made meats are less wholesome than fresh meats.

Poisons in milk. — Milk may carry germs and in this way infect persons using the milk. To prevent this the

[1] Voluntary vaccination. [2] Compulsory vaccination.

In the years 1908–1911 the vaccination was voluntary. Beginning in 1912, it has been compulsory. Since 1912, the cases of typhoid 27, 4, 7 were in men who were not vaccinated, for some reason or other, or who had contracted the disease before enlistment, with few exceptions.

milk is often pasteurized* (heated from 150° to 155° F. for 20–30 minutes). In preventing the transmission of disease germs, greater emphasis should be placed on the method of obtaining the milk. The dairyman should have clean pails, and clean hands, and the udder of the cow should be cleaned before milking. The farmer who takes the milk pail from the fence and, without washing his hands, milks the cow which has been standing in a dirty stable, is not getting clean milk. Furthermore, he is neglecting a duty and responsibility he owes to his family and his neighbors.

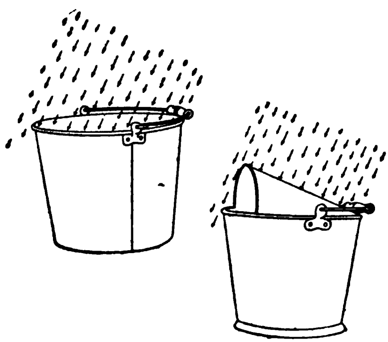


FIG. 218. — Two kinds of milk pails. The open pail admits the dirt; the covered pail keeps much of it out.

The poisons and dirt in milk are real sources of danger to the body, but they can be eliminated by careful gathering and distribution of the milk supply. The cows should be cared for in a sanitary stable and every means used to keep them clean and healthy. Cows should be cleaned preparatory to milking. Covered pails for milking should be used in order to keep the milk free from dirt (Fig. 218).

It is also very important to keep the milk clean after it is gathered. All bottles should be sterilized* and the hands should not come in contact with the milk or inside of the bottle. The best method of bottling milk is by machinery. Milk is sometimes sold in bulk, from cans. Such milk, even if gathered carefully, is liable to be contaminated. Flies and dirt should not gain access to the milk at any time. Compare the two pictures in Figure 219 and be prepared to state all the advantages in the method shown in the lower

picture. In spite of the care exercised in many places in gathering the milk, a certain amount of infectious material gains entrance to the milk after it is gathered. To prevent

Courtesy of Metropolitan Life Ins. Co.

FIG. 219. — Two ways of distributing milk.

these organisms getting into the body and so causing disease, pasteurization is very widely practiced. Communities after pasteurizing the milk supply have noticed a drop

in the amount of sickness and number of deaths. When the infants in the care of the City of New York (Randall's Island) were fed on milk that was not pasteurized the death rate was as follows:

Year	Number of Children	Number of Deaths	Percentage
1895	1216	511	42.02
1896	1212	474	39.11
1897	1181	524	44.36
Total	3609	1509	41.81

This milk was gathered from a carefully selected herd pastured on the island. In the early part of 1898 a pasteurizing plant was installed on the island and the milk given to the children was pasteurized. No other change was made in the diet. The record for the next seven years was as follows:

Year	Number of Children	Number of Deaths	Percentage
1898	1284	255	19.80
1899	1097	269	24.54
1900	1084	300	27.68
1901	1028	186	18.09
1902	820	181	22.07
1903	542	101	18.63
1904	345	57	16.52
Total	6200	1349	21.04

It will be noticed that the total number of deaths in seven years is less than the total in three years with raw milk. Professor Fisher gives the value of a human life in dollars

as being $950 at the age of five years. Counting the average of these infants to be five years, what was the yearly saving to the city by the installation of this plant. Beyond this hypothetical saving there was a real saving in nursing and hospital supplies, medical care, and the cost of burial.

Injury of the body by physical agents. — The body may be injured by forces coming in contact with it from the outside. These forces may be bacteria or they may be heat, chemical, etc. The prevention of injury due to physical forces will be important and of value in maintaining our health.

Heat exhaustion. — The main cause in this is heat. It may come from the sun or from a furnace. Individuals who indulge in alcohol are easily attacked. It occurs often in armies on the march. Clothing fit only for cold weather worn on hot days predisposes one to sunstroke.

Sunstroke. — This condition is caused by the sun's rays. Care must be taken not to expose the body to too great

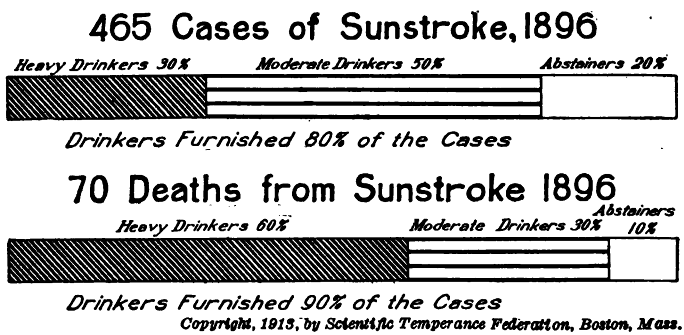


Fig. 220. — Alcohol and Sunstroke. Statistics U. S. Weather Review, November, 1896.

heat of the sun. The clothing in hot weather should be light and loose. Alcohol in any form lowers the resistance so much that sunstroke easily occurs in persons who use it (Fig. 220).

Electricity. — Great electrical plants, used in industry, are a source of danger. Individuals should not go near these machines unless engaged in caring for them. In no case should one enter a dynamo* room with wet clothing. Electric wires and connections in the home should be insulated and repairs should always be made by an electrician.

Mountain sickness. — When coming into a mountainous region from low altitude, care should be taken not to engage in mountain climbing the first day. Time is necessary for adjustment of the body to the new conditions. Mountain climbing should be engaged in only by the vigorous and strong.

Caisson disease.* — Men who work underground in tunnels and mines in an air of high pressure suffer cramps and paralysis on emerging into the air above ground unless the ascent is very gradual. Laws in some states compel employers to control this change. But for such workers it is very important to know that "bad physical health, diseases of the kidneys or heart, alcoholism, obesity, and hunger are contraindications* for subjecting one's self to the high atmospheric pressure."

Injury of the body by chemical agents. — Chemicals, when brought in contact with the skin, may burn it, and when taken into the system they injure the body cells.

Lead poisoning. — Alcoholism again plays a prominent part in increasing the susceptibility to lead poisoning. Lack of cleanliness is also to be considered, and workers in industries where lead is used should have the hands clean when food is eaten. There is a popular tradition among lead workers that chewing tobacco is a preventive of the disease but this is not so.

The most dangerous trades connected with the use of lead are, lead mining and smelting, zinc smelting, working in white lead and lead colors, making lead pipes and other lead objects, type making and type setting, and working in

electric storage-battery factories. Painters and workers in ceramics and rubber goods frequently suffer from the lead used in manufacture, if they are not careful. Cleanliness

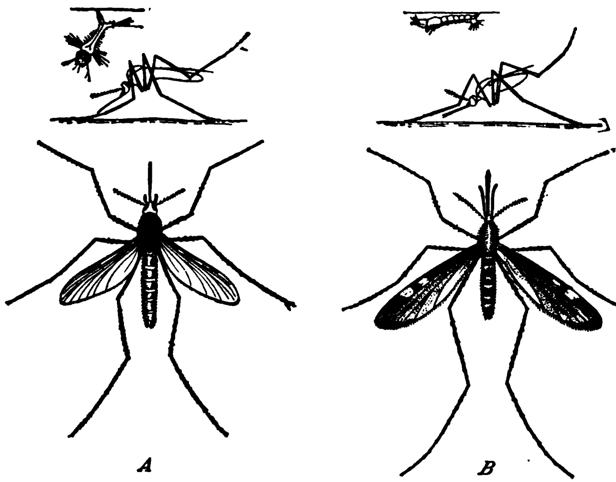


FIG. 221. — Mosquitoes. Comparison of —

The non-malarial Genus Culex.	The malarial Genus Anopheles.
Palpi short.	Palpi long.
Wings not spotted.	Wings sometimes spotted.
Legs sometimes spotted.	Legs not spotted.
Position at rest, parallel to surface.	Position at rest with abdomen and hind legs elevated at an angle to surface.
Larva, or wiggle-tail, breathes, and rests perpendicular to surface of water.	Larva, or wiggle-tail, is parallel to surface of water when it breathes.

The sucking tube and feelers are long in both genera. The long palpi of the malarial genus furnish an infallible sign. The palpi are found on each side of the sucking tube. The feelers are next to the palpi.

and avoidance of alcohol are the things to be remembered by these workers.

Other poisonous metals. — Mercury, phosphorus, tin, copper, brass, and zinc poisoning occur among workers with these metals. Pure air in the factory, sanitary floors and

windows, cleanliness in the worker, avoidance of alcohol — these are the measures for prevention.

Diseases caused by mosquitoes. — It has been learned that the mosquito can carry parasites * in the salivary glands and inject them into the blood of man with its sting.

Malaria. — This disease is caused by the bite of a particular mosquito, called the *anopheles* (Fig. 221), which at some time before has bitten a person having malaria. You

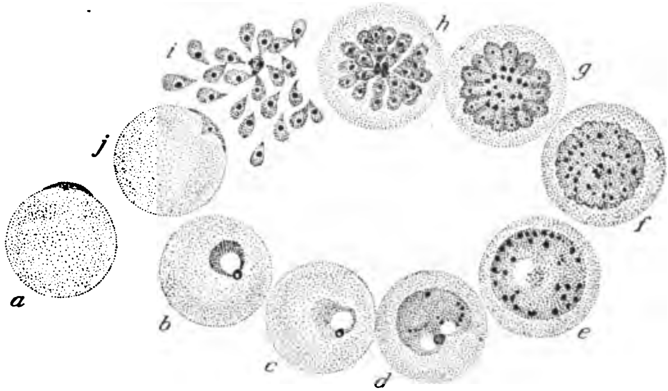


FIG. 222. — Reproduction of the malaria parasite in a red blood cell. *a*, entering the cell; *b*, within the cell; *c-h*, development and segmentation of the parasite; *i*, rupture of red cell setting young parasites free; *j*, one of them entering a red cell. This process goes on with continual destruction of the red blood corpuscles until the parasites are killed by medical treatment.

see in this way the mosquito transmits the disease. Prevention aims, therefore, to kill mosquitoes of this particular kind and to prevent the mosquito from biting a person having the disease. The mosquito breeds in water and so the breeding places of the insect should be destroyed. Stagnant pools and swamps are covered with oil which kills the young. Empty cans on rubbish piles should be buried so that no water can collect in them. Boy scouts may do a "good turn" by organizing a "Mosquito Day." Mosquitoes may

be stunned in the house by burning fresh leaves of eucalyptus or pyrethrum powder and then killed before they revive. Persons in malarial regions and persons suffering from malaria should live in houses that are well screened.

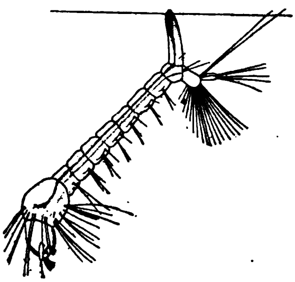


FIG. 223. — Larva of a culex mosquito.

A person does not get malaria from bad water, food, exposure to sun, night air, or in any way except by the bite of a mosquito which has sucked the blood of a person who has malaria. The mosquito serves to transmit the parasites which cause the disease, and they are transmitted in no other way.

When a mosquito, which has previously bitten a person having malaria, bites another person, the parasites are conveyed into the blood of the second person. These parasites enter the red blood cells and develop and increase in number as shown in Figure 222.

The female mosquito lays her eggs on the surface of stagnant or still water and in a few days these hatch into larvæ,* often called " wigglers." The larvæ develop into pupæ and finally into mosquitoes. All stages in this development occur in water. The larvæ of *anopheles* require from twelve to sixteen days in warm weather to mature. These larvæ may be distinguished from the larvæ of other and harmless mosquitoes by the position they take in the water. The *anopheles* live at the top of the water and parallel to its surface (Figs. 223, 224).

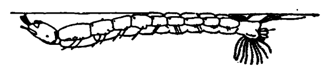


FIG. 224. — Larva of anopheles mosquito (modified after Howard).

The *anopheles* can best be destroyed by getting rid of them in the larval stage. All brush and weeds surrounding dwelling houses and mosquito breeding places should be cut

down. The breeding places can be destroyed by draining, filling, or oiling. By draining or filling, the water necessary for the deposit of eggs is removed; by oiling the water, a thin film of oil is formed that prevents the larvæ from getting air and so they die. If oiling is the method chosen, it should be done every fourteen days.

Yellow fever. — This disease at one time was not controllable because it was not known how the infection * was carried. Now it is known that the mosquito, *Stegomyia fasciata,* carries the disease. The preventive measures in malaria apply here.

Tuberculosis. — As the tubercle bacilli (Fig. 225) multiply in the body, tiny tubercles are formed; hence the name. Tubercles are growths shaped like pin heads, and they may be formed in any tissue of the body. You have learned that in thousands of cases bacilli injure a part of a lung and it heals over. But in thousands of cases the individuals have lived wrong physically for so long, and their lungs have become so weak, that they are gradually destroyed by the bacilli.

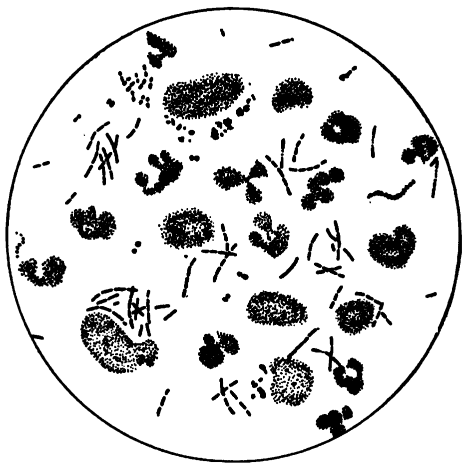


FIG. 225. — Tubercle bacilli in sputum of a person having tuberculosis of the lungs.

Whether the body has been injured through ignorance or self-sacrifice, through dissipation or selfish ambition for money or fame, through foolish attempts at beauty, through devotion to learning, or through some unselfish love and

work for others, the result is the same; nature knows no difference. However noble the character or wise the mind, when a vital organ has sunk in health below the standard necessary for a human being, deterioration comes.

Bacilli may be found in the sputum in an early stage of tuberculosis. Then recovery is more difficult, but it will often come if the person returns to natural ways, living out of doors and allowing the forces of health to purify the body.

Many people die from tuberculosis and yet in many cases the disease would not occur if proper care had been exercised by the individual, or by those who have the disease. If one who has the disease is careless and distributes the germs and if those who have not the disease are careless in matters of hygiene, there exists a situation which makes it easy for one person to infect many. No one desires this to occur. All must work against such spreading of infection.

Now it is known that the sun's rays destroy the bacillus of tuberculosis. A man by the name of Twitchell found that the sputum containing tubercle bacilli exposed to direct sunlight for seven hours, could not produce the disease, and the same sputum kept in a closed darkened bedroom with carpeted floor and heavy hangings, caused the disease even after thirty-nine days. Are the sun's rays valuable? Should the floor be covered with carpets or with rugs?

Children from earliest infancy should be accustomed to fresh air. Babies four weeks old should be taken out of doors and even newborn babies should sleep in a room with the window open. If the baby at home is bottle fed, the milk used should be from cows that have been tested by tuberculin * for tuberculosis and the milk should be pasteurized. Do you know of a baby living on cow's milk? Is the milk pure? Is the milk pasteurized?

Prevention of communicable diseases. — Many of the diseases of the body are caused by the germs of the disease gaining entrance to the body. If the entrance can be pre-

vented, the disease will be prevented. In addition, the body must be made strong and healthy so that the germs which break through the blockade, Health Care, will be destroyed by the forces present in the body. To prevent the entrance of germs we should consider:

Cleanliness of the mouth. — The teeth must be kept clean by brushing at least twice daily. All cavities must be filled.

Drinking water. — The water used for drinking should be pure. Pure drinking water is tasteless, odorless, sparkling, without organic matter, and without disease germs.

Clean food. — Food taken into the body to build our bodies should be clean. People should never eat at dirty restaurants. If restaurants were chosen on the basis of cleanliness, by all people, there would not be any dirty ones left — they would have to " clean up " or " get out." Children in the cities should not buy food from street venders who expose their food to dust and dirt and flies.

Care of the bowels. — The waste of the body must be removed daily and regularly. The best time for this elimination to occur is after breakfast. No exception to this habit should ever be allowed.

Bathing. — The body should be bathed daily in certain parts, and the entire body should be washed at least once a week. A shower bath is the most sanitary form of bath. Rural schools and homes without running water can arrange for showers by providing a perforated pail suspended so that it can be filled and can distribute the water in a spray.

Sleeping. — One should be accustomed to fresh air and, therefore, open windows at night are very important. Even in cold weather the window of the sleeping room should be partly open. The number of hours of sleep which children of different ages should have are given on page 325.

Prevention of influenza. — The very serious epidemic of influenza in the United States in the fall of 1918, caused more deaths in the army and civil population " over here "

than were caused by German bullets in the U. S. Army "over there." In prevention of the disease, the factors which have been repeatedly mentioned as important hygienic practice, are the ones most effective. In this connection it is instructive to learn the memorandum for strengthening personal resistance, which was issued September 27, 1918, by the Office of the Surgeon-General, U. S. A.

"HOW TO STRENGTHEN OUR PERSONAL DEFENSE AGAINST SPANISH INFLUENZA"

1. Avoid needless crowding — influenza is a crowd disease.
2. Smother your coughs and sneezes — others do not want the germs which you would throw away.
3. Your nose, not your mouth, was made to breathe through — get the habit.
4. Remember the three C's — a clean mouth, clean skin, and clean clothes.
5. Try to keep cool when you walk and warm when you ride and sleep.
6. Open the windows — always at home at night; at the office when practicable.
7. Food will win the war if you give it a chance — help by choosing and chewing your food well.
8. Your fate may be in your own hands — wash your hands before eating.
9. Don't let the waste products of digestion accumulate — drink a glass or two of water on getting up.
10. Don't use a napkin, towel, spoon, fork, glass or cup which has been used by another person and not washed.
11. Avoid tight clothes, tight shoes, tight gloves — seek to make nature your ally, not your prisoner.
12. When the air is pure breathe all of it you can — breathe deeply.

Charles Richard, Brig. Gen. M. C., Act. Surg.-Gen. U.S.A.

It will be seen that we must be careful to keep our bodies so strong by careful living that no germs can enter. The following table shows the ways and means of infections that are common and important:

TABLE OF THE WAYS AND MEANS OF COMMUNICATION OF THE IMPORTANT INFECTIONS OF MAN

Disease	From Contact with Sick Person or Animal	From Contact with Things Sick have Used	Drinking Water can Carry the Germ	Food can Carry the Germ	Air can Carry the Germ	Animals can Carry the Germ	Insects can Carry the Germ
Anthrax . .	yes	yes		yes	yes	cattle	flies
Cholera . .	yes	yes	common way	yes			flies
Diphtheria	common way	bedding etc.		yes	yes		flies
Erysipelas .	yes	yes		yes			
Influenza .	chief way	yes			yes		
Malaria . .							mosquito only
Measles . .	common way	yes			yes		
Mumps . .	yes	yes			yes		
Rabies . .	only way					dogs	
Scarlet fever . .	common way	yes		yes, milk	yes, skin		
Trachoma .	common way	yes, towels, etc.			yes		flies
Tuberculosis . .	yes	yes		yes, milk	yes	cattle	flies
Typhoid fever . .	rarely	yes	common way	yes, milk			flies
Wound infections such as cuts, boils, etc. .	yes	yes		yes	yes		flies

How bacteria are destroyed within the body. — If, in spite of keeping the body in a splendid condition of health, virulent bacteria gain an entrance to the body, even then the body is often able to defend itself successfully by the following forces at its disposal:

First — The white blood cells have as their chief function to seek out bacteria and to devour and destroy them. This explains why so many germs are necessary to transmit a disease. If only a few are present, these cells will be able to protect the body. If the infection is too great, or if the infecting bacteria are too virulent, then these cells may fail (Fig. 226).

Fig. 226. — *A*, germ destroyed by white blood cell; *B*, cell destroyed by germs and the germs multiplying.

Second — The plasma of the blood contains substances which are able in some way not fully known to inhibit the action of bacteria. These substances are called antibodies * and are developed by the body during the course of the infection. Now these defenses are dependent in a very definite way upon the general health of the body for success. The action of these cells is more pronounced in one with vigorous health. It has never been proved that bacteria will cause disease in a perfectly healthy body and, therefore, it is important to keep the body in a fine state of health, in order to prevent the great loss occasioned by illness. It is perfectly true that many bacteria seem to be harmless under certain conditions, but, if they find a weakened condition, they seem to change their nature and begin the formation of poisonous toxins. Disease occurs then in a large measure because people do not care for themselves properly.

How bacteria are destroyed outside the body. — The sun is the great destroyer of all bacteria in summer and in tropical climates. Cold destroys them in winter and in cold climates. Wind drives away bacteria. It is almost impossible to transmit disease in the open air. Some germs feed upon other germs. In the soil are certain kinds of germs which oxidize all organic matter, including other kinds of germs. Thus germs can filter through only a few feet of sand before they are destroyed. Well-water is safe to drink if no impurities reach the soil near the well, but where the ground becomes soaked with germ-laden sewage, impurities penetrate farther and well-water is unsafe.

Cleaning with soap and water removes germs. Drying kills many germs, but some species are harder to kill when dry; in that condition they will stand even freezing. Heat equal to that of boiling water, applied for 15 minutes, will kill almost every kind of germ. If the germs are killed by a boiling temperature it does no harm to leave air in the top of canned vegetables and jars of preserves. Milk is a nourishing soil for germs which cause stomach trouble with bottle-fed babies, unless the milk has been pasteurized and the bottles sterilized.

Disinfection. — For many years it has been the practice to disinfect the rooms of people recovering from communicable diseases, such as measles and diphtheria. The idea expressed in such a procedure was to kill the germs that were in the room inhabited by the sick person. In Providence, R. I., and New York City this practice has been abandoned and health officers in other places are paying more attention to cleanliness by soap and water. It is true that any article that has come in immediate contact with the sick person, as utensils, books, toys, and personal articles, should be disinfected at the end of the communicable disease. The danger with continuing such a practice as terminal disinfection is that it places the emphasis in the wrong place and

makes people believe that the danger lies in the room and its hangings. The danger lies in coming in contact with the person having the disease and allowing that person to cough or breathe in your face. Doctors and nurses generally escape the communicable diseases because they are very careful about washing their hands and protecting themselves from coughs. We will not fear infections when we are intelligent enough to avoid the real dangers and do not allow ourselves to be deluded by a false security.

*Antiseptics.** — There is a considerable interest to-day in preventing disease and many people are impressed with the large number of antiseptics on the market. Everything on the market used by people in a personal way claims some particular antiseptic feature. Tooth powders, shaving soap, gargles, and numerous other articles claim this feature. Now, the important thing for us to remember is that the antiseptic day has passed and we are living in an age that is emphasizing the aseptic feature in both sanitation and surgery. Surgeons do not employ antiseptics as formerly in the care of wounds; they use aseptic measures and keep the wound clean. It is true that badly infected war wounds are treated to-day by a new and powerful antiseptic, known as the Carrel-Dakin solution, but sanitarians to-day depend upon cleanliness and isolation of the sick person, and pay scant attention to antiseptics and disinfectants. The modern method in housekeeping is to keep the house clean and avoid the spring house cleaning; the modern method in disease prevention is to keep the sick isolated from the well, to keep the sick and the well clean, and not try to kill the germs after dirty habits of living have allowed severe infections to occur.

A curious theory of disease. — There is an artless theory, common among unlettered people, which holds that disease is a distinct thing, and that when God made the various diseases, he made plants to grow, each of which contains the infallible remedy for one of the diseases. Such persons when

they are ill, and after various treatments remain ill, cherish the firm conviction that if they could only find the right remedy that is growing in some plant, somewhere in the world, they would immediately be cured, without any attention to hygiene and the conditions necessary to health and its recovery. Patent medicine venders particularly foster this idea, although each one illogically adds that his medicine will cure all diseases indiscriminately.

This simple theory is opposed to all the facts. The poisons in plants are waste products that the plant seeks to remove. They are, therefore, found mostly in the parts of the plant that will be shed, as the leaves, seeds, and bark. The poisons serve meanwhile to protect the plant from animals. The only animals (besides man) that will touch the tobacco plant are the goat and the tobacco worm; their bodies seem to have become used to the poison. No sick cat eats nightshade, no sick cow eats jimson weed. The very bitter or repulsive taste of most poisons shows them to be unsuited to the animal body. No child would drink a liquid containing the bitter alkaloid,* caffeine,* unless it were influenced by the example of its elders, and the bitter taste were disguised with milk and sugar.

HEALTH RULES FOR SCHOOL CHILDREN

(From Public Health News, State Department of Health, New Jersey.)

The " DO " Rules, or What to Do to Prevent Disease

1. Keep away from houses where any one is sick with infantile paralysis or other communicable disease.
2. Keep away from sick people and those who have been in contact with sick people.
3. During an epidemic, keep away from crowds.
4. Destroy all discharges from the nose and mouth.

5. Always cover your mouth with a handkerchief when you cough or sneeze. If you cannot get a handkerchief, use your hands and then wash them at once.

6. Keep away from flies and keep flies away from you. Flies carry germs on their feet and in their stomachs.

7. Wash your hands with soap and water upon rising in the morning, before each meal, after each visit to the toilet, after coughing or sneezing in the hand, and before going to bed.

8. Keep clean. Take a bath every day and see that all clothing worn next to the skin is clean.

9. Kill all vermin such as bedbugs, roaches, and body lice.

10. Keep your books, your pencils, and your desk clean.

11. Eat plain, wholesome food, including plenty of milk and vegetables.

12. Keep the milk clean, covered, and cold.

13. Protect all food from flies.

14. Wash all food that is to be eaten raw.

15. Keep down dust. Always sprinkle floors with sawdust, old tea leaves, or bits of newspaper, which have been thoroughly dampened, before sweeping. Never allow dry sweeping.

16. Brush your teeth daily, or better, twice a day.

The "DO NOT" Rules, or What to Avoid to Prevent Disease

1. Do not go near sick people or the houses where they live.

2. Do not go in crowds during an epidemic.

3. Do not kiss anybody on the mouth, and do not let anybody kiss you on the mouth.

4. Do not cough or sneeze in anybody's face or over food.

5. Do not put your fingers or pencils in your mouth or nose.

6. Do not spit or blow your nose on the floor — use a handkerchief.

7. Do not bite the corners of your books.

8. Do not spit on your hands when you play ball.

9. Do not bite an apple, candy, or other food that some one else has been eating.

10. Do not eat food that flies have walked over.

11. Do not eat with dirty hands — wash them.

12. Do not eat with your fingers — use a fork or spoon.

13. Do not handle foods that others are to eat unless your hands are absolutely clean.

14. Do not eat foods that have been handled by unclean hands.

15. Do not eat apples, pears, or other raw fruits from the market until they are carefully washed.
16. Do not stir up the dust either at home or at school.
17. Do not drink out of a cup that other people have used.
18. Do not wipe on a towel used by any one else.
19. Do not lend your pencils or books to others.
20. Do not borrow books or pencils, but have your own and keep them for your own use.
21. Do not trade chewing gum, candy, horns, or whistles.
22. Do not wipe your nose on your hand or sleeve — use a handkerchief.
23. Do not use a soiled handkerchief — get a clean one.
24. Do not wet your finger on your tongue to turn the leaves of a book.
25. Do not have dirty hands — wash them.

GLOSSARY

Alkaloid. — An organic base containing nitrogen, (a base is a compound capable of uniting with an acid and forming a salt), and having powerful poisonous effect upon the animal body. Alkaloids are of vegetable origin.

Antibodies. — Substances developed in the blood during the course of a disease. They are the chemical factors in the immunity conferred by the disease.

Antiseptic. — Preventing fermentation and decomposition. Preventing the growth of bacteria.

Antitoxin. — A serum for the treatment of diphtheria. It is made by injecting *Bacillus diphtheriæ* in a horse and after the horse has developed the antibodies of immunity, the serum of the blood of the horse is taken and certain graduated amounts used in treating diphtheria in man.

Caffeine. — An alkaloid found in coffee.

Caisson. — A large water-tight box in which work is done below the water level. The pressure of the air in a caisson is higher than in ordinary atmosphere.

Cholera. — An acute epidemic disease caused by the *Bacillus of Koch*, a comma-shaped bacillus.

Contraindication. — A sign or symptom indicating the inappropriateness of the procedure.

Dynamo. — A machine driven by steam or some other force which converts the energy of the machine into electrical energy in the form of an electric current.

Fungus. — A plant without chlorophyll that derives its nourishment entirely from organic compounds. It will be remembered that plants having chlorophyll obtain their nourishment by using inorganic compounds.

Immunity. — A condition developed in the body either actively by the individual or passively by an operator. Active immunity results in the course of a disease by the formation of antibodies in the blood. Passive immunity is developed by injecting into the blood an immune serum such as antitoxin, or by such a process as vaccination.

Infection. — A condition developed in the body by the entrance of disease-producing organisms into the body.

La Grippe. — An acute epidemic disease caused by the *Bacillus influenzæ*. It is easily communicable and should be avoided.

Larva. — One of the forms of an animal after leaving the egg form and before it appears like the parent. This type of development is seen especially in insects.

Lockjaw. — The popular name for a disease that shows by an early affection of the jaw muscles. The disease, *tetanus*, is caused by the *Bacillus tetani*. This organism is prevalent in soil especially around barnyards and richly fertilized fields.

Microbe. — A name sometimes used for bacterium or germ.

Mold. — A fungous growth occurring in warm moist places and seen especially on food, walls, and clothing.

Obesity. — A condition of great fatness with accompanying unsoundness.

Parasite. — A living organism that lives on or in another, called its host, from which the parasite derives its nourishment.

Pasteurize. — To heat milk to a temperature from 150° to 155° F. for twenty to thirty minutes, for the purpose of destroying the bacteria of the milk. This method was originally proposed by Pasteur, a great French scientist.

Plague. — A pestilence or severe epidemic disease. In the middle ages plagues were common. To-day they are less common because we know the causes of them and how to combat their spread.

Ptomaine. — A poison developed in food by a process of fermentation and decomposition.

Quarantine. — Preventing for a fixed period of time (originally forty days, *quadraginta*, forty) communication with persons, ships, or goods arriving from ports infected with communicable disease.

Serum. — The plasma of the blood is called the serum, but the term is also used to designate the material used for immunizing purposes. Antitoxin is a serum and is made from the plasma of a horse.

Sterilize. — To make sterile, without life. By a process of heat or chemicals to destroy all the bacterial life on an instrument, gauze, etc.

Toxin. — The poison developed by bacteria.

Tuberculin. — A liquid prepared by growing *Bacillus tuberculosis* in a broth culture.

Vaccination. — A process of developing in man immunity to smallpox by causing a mild form of the disease when the smallpox virus is rubbed into a small opening in the skin of the arm or leg.

Vaccine. — A preparation of the weakened or the dead bodies of bacilli used to inject into man for the purpose of developing immunity to a particular disease.

CHAPTER XX

THE EFFECT OF ALCOHOL AND TOBACCO

I. The Body as a Storehouse of Energy.
II. The Meaning of Fatigue.
III. The Effect of Stimulants on Energy and Nerves.
  Artificial stimulants
  Natural stimulants
IV. Alcohol.
  As a food
  As a poison
  Summary of the effects of alcohol
V. Tobacco.
  General effects of tobacco
  The effects of tobacco upon youth

The body as a storehouse of energy. — Succi, an Italian, successfully accomplished a fast of fifty days in London, being constantly watched to make sure of his fasting. There is reported, on good authority, a case of an insane person who suddenly became possessed by the idea of taking no food, and who lived sixty days before starving to death. Long fasts are a great injury to the body, no doubt, but what can be learned from such experiences? Certainly it shows the wisdom with which we are made and that our physical organization is very provident.

Once some miners were shut in by caving of part of the mine. But unlike the cases mentioned above they were without water as well as food. When, by digging, the rescuers reached them, seven days after, several were still

found alive, although most of them had succumbed. The miners, no doubt, had nourishment in their bodies for some weeks more of life, but the necessary solvent in the form of water was lacking to dissolve it and bring it within the reach of the cells most needing it.

This fact concerning the amount of nourishment stored in the human body (in one case a two months' supply !) is one of the most stupendous facts with which the science of physiology has to deal, and it should be borne in mind, or we may greatly deceive ourselves about some very simple matters. Did you ever get so tired that you had to give up and stop, however much you would have liked to continue at work or play? To rest was the wise thing to do. Now, although you learn from physiology how much energy you have stored up within your frame, you should not on that account, be tempted to go on until you almost break down. Probably you know people who are conceited about their bodies and say they are made of cast iron; nothing can hurt them. Did you ever know anybody who was conceited about his mind and thought he was very bright? It is just as foolish to be conceited about the body. It is a very wise arrangement that under ordinary conditions we cannot get at the surplus energy we have. We are compelled to be provident, as it were; yet stimulants and narcotics, by irritating the cells, will cause them to expend some of this reserve energy; they will enable man to get at this precious store which he should save for emergencies, such as a period of sickness when he cannot digest food, or some time when he is making some mighty effort. This reserve energy will enable him to undergo some trying ordeal successfully. Did you ever know of a weak, sick man who had eaten very little for weeks, yet was so powerful that it took several strong men to hold him? This sometimes happens in the case of sick men who are delirious and crazed with pain and with the poisons formed in their bodies during illness.

The meaning of fatigue. — Suppose you are tired or worked out. The fatigue depresses you, and you feel discouraged. What ought you to do? Why, rest, of course, and you will soon feel all right again. This seems very simple, yet some people will not do this way, but take an alcoholic beverage or tobacco, which will keep them from feeling tired when they are tired. If you have been working hard preparing for examinations, or gathering hay, or attending to some important business, or have been under the excitement of some pleasure trip, and feel blue and worn out, then bear the result like a man, or like a true boy or girl, as the case may be. Giving up for a while, or " toughing it out " with the blues, or losing a little time from business, will not hurt you but will make you strong, while a stimulant would leave you less of a man than before.

There is only one source of energy for man's body, and that is the union of food and oxygen. He must get his energy from the same source that the engine does, and that is from his food, which serves as fuel, and the oxygen that burns it. The millions of little workers, the cells, will store up food within themselves and get rid of the ashes and refuse, and the pure, sound body will be ready for work again.

The effect of stimulants on energy and nerves. *Artificial stimulants.* — You remember those wonderful little one-celled animals, the amœbas. If poison is brought near, they will try to escape it. They also throw out the impurities generated by their own life processes. If anything touches one roughly, it will draw back from the danger. Likewise, if a man takes poison, such as alcohol or tobacco, into his body, the cells will try to throw it off. The heart, although it may be already tired, goes to thumping anew, secretions are poured out by the cells to dilute and weaken the poison, and the great activity excited diverts the man from noticing his fatigue, and makes him think the poison has given him renewed strength. It is the same as if he thought the whip

instead of the oats gave the horse strength. The horse, like the cells of the body, is only trying to avoid something harmful, and like them, he uses up his strength in so doing. After a while he will be very stiff and tired. There is no artificial stimulant that does not cause a reaction. The stronger the stimulant, the worse the poison. Strychnin* is one of the deadliest poisons known, and also one of the most powerful stimulants. If an animal is given strychnin, its nerve tissue is sometimes reduced to such an irritable condition that a loud sound, or merely touching any part of it, will throw every muscle of its body into a spasm.

Some people are coffee topers and tea topers. It is a mistake to say these drinks quiet the nerves. Who is so nervous as the old lady who drinks frequent cups of tea to quiet her nerves? It is the tea that is making her nerves unsteady. Some people unaccustomed to tea will lie awake most of the night, wearing out their energies by sleeplessness if they drink only one cup of it.

It is easy to understand how a person sitting up with a friend who is dangerously ill will take tea or coffee to keep him wide awake. If he has some great duty to perform, or trust imposed upon him that will soon be over, there may possibly be some reason in stimulating his activities, even if he must suffer reaction and depression thereafter. But why one will habitually disturb his body with narcotics, such as alcohol, tobacco, or even mild narcotics, such as tea and coffee, so as always to keep his vital force and reserve energy at a low ebb, is difficult to understand. It can only be explained by ignorance of the fundamental laws of his being.

Natural stimulants. — The chief natural stimulants are cold air, sunlight, pure air, physical exercise, interest, joy, and other wholesome emotions. A deep breath of pure air is a better stimulant than a glass of beer; climbing a hill or sawing a log of wood will make the blood flow faster than an alcoholic drink will; a pleasant talk with a friend is a

better sedative* than a cigar; a cold day will steady the nerves better than an opiate*; a trust that a good Power rules over all will drive away worry quicker than cocaine; a cold bath will bring steadier nerves than coffee; a cold wind will give a better appetite than food soured with vinegar or hot with pepper. Natural stimulants do not produce a reaction because they do not excite the body to an injurious degree, nor cause the energies to be consumed beyond the danger point. Persons who go through life under the stimulus of these natural blessings have sound steady nerves and clear brains. They do not have to take anything "to quiet their nerves."

Man's body was beneficently designed to keep a large amount of energy stored up, so that he can feel conscious of his power and go through life buoyantly and happily, and prepared for all emergencies, — the highest being in the world that he inhabits. He is in a world full of interest. Delicious fruits and nutritious nuts and grains abound to awaken and satisfy his appetite. The bright sun not only shines upon his skin, but deep into it, and stimulates the cells; the fresh breezes striking his nerves, start currents coursing through his body. The oxygen penetrates to every cell, purifying and awakening to life. The pleasure of association with his fellow-creatures, and various other pleasures, arouse him to do his part in the world. There is no need to seek in the jungle for some bitter berry, or among the weeds for some nauseating leaf, or among decaying apples or grapes or fermenting grain for a burning and revolting liquid in order to stir his being to action. He lives the life for which his body was designed.

Alcohol. — In 1914, during the progress of the Great War, Russia prohibited the manufacture and sale of vodka, the alcoholic drink in general use in Russia before that time. The effect upon the people of this forced abstinence was remarkable. Savings banks sprung up in every village where

before poverty was predominant; efficiency in all phases of Russian life increased; and the nation by this act alone played a more important part in the war than would have been possible otherwise. The question, "Is alcohol a food?" was answered by the Russian in terms of greater national efficiency by the removal of alcohol from the diet.

After a rapid increase in prohibition in the United States, Congress in 1917 passed an amendment to the Constitution submitting the question of national prohibition to the state legislatures. By 1919, forty-five state legislatures had ratified the amendment. The most important argument for national prohibition has been the argument to conserve the food of the country, because in the manufacture of alcohol essential grains of the food supply are used in large quantities. There has been, also, an increasing appreciation of the loss in efficiency in those who use beer and whisky, and with the whole nation training to become efficient, the use of alcohol has been cast aside as an unnecessary incubus.

There are some people, however, who believe that alcohol is a food. They seek to justify its use on this ground.

Alcohol as a food. — When alcohol is taken, about ninety-five per cent of it is oxidized and changed into carbon dioxide and water. This was found out many years ago and raised the question as to whether it should be classed as a food. Investigations were made, and the result was that alcohol was classed with the poisons and not as a food. The question has been reopened several times in the last half-century, but always with the same result. Scientific men generally continue to classify it as a poison and not as a food. Morphine, mushroom poison, strychnin, and other dangerous poisons are oxidized in the body and yield up their energy, yet they are recognized as poisons. A substance cannot be classified as a food simply because it is oxidized in the body.

Leading scientists define a food as a substance of such a

nature that, when absorbed into the blood, it nourishes the body without injuring it.

Sugar is a food, but a solution of sugar can undergo a change caused by the growth of millions of yeast plants and the food is lost. The change is called fermentation, and alcohol is one of the poisonous products of this process of decay or fermentation.

The condition of the body after it has oxidized alcohol is quite different from its condition after it has oxidized sugar or bread. Benzine* is very easily oxidized. If poured upon the fire of a locomotive, it would make the water boil so rapidly that there would be danger of straining or bursting the boiler. It would burn so rapidly as almost to make an explosion, and a very large part of the heat caused by the oxidation would be lost. A stove needs a slower burning substance than gunpowder or benzine. A locomotive needs a slow-burning fuel which will develop heat at such a rate that it will be possible to utilize it. The body needs even slower burning substances than the locomotive, sugar, starch, and fat; not a more rapidly burning substance, such as alcohol, which in burning will weaken the tissues and shock and injure the delicate cells of the one who drinks it. In the chapter on the blood it was learned that alcohol does not even cause a gain of heat in the end, since the paralysis of the capillaries resulting from a drink causes the warmth to be taken to the surface and escape, so that the body is cooler than before the drink.

True food does not burn in the blood; it is stored in the cells in the form of very unstable compounds. These compounds break down under the stimulus of oxygen and the nerve impulse, and set free energy. The cells of the nerves and muscles correspond to the furnace and steam chest of the engine. Suppose, instead of pouring benzine into the furnace, you burned it in the cab or the smokestack. Do you think it would increase the power of the locomotive?

Alcohol is not stored in the cells, nor does it enter into combination to form the energy compound, the breaking down of which sets free the energy stored up. Alcohol burns quickly after entering the body; a large part of it, indeed, never gets beyond the liver, and is burnt in this long-suffering organ. But some of it gets into the general circulation, and is distributed throughout the body, irritating the nerve cells and poisoning them and every other tissue.

Alcohol may not be considered a food, therefore, because it is not a tissue builder, as are the proteins, and it is not stored in the body, as are the fats. In addition, since it has a toxic action, it injures the body when taken in excess. This may be the case with other foods, but they give warning when taken in excess. Alcohol as a food is exceedingly expensive. Dr. Woods Hutchinson has said, "as a food, alcohol is a joke and a bad joke at that."

Dr. D. B. Armstrong gives the following figures in tabular form to indicate just how expensive alcohol as a food would be (food is useful to the body primarily as it gives energy, and its power to produce energy is dependent upon its caloric value).

APPROXIMATE FOOD VALUE FOR TEN CENTS

Article	Calories for Ten Cents
Sherry	30
Beer	240
Sirloin Steak	375
Eggs	450
Bread	2180
Corn meal	3310
Oatmeal	3720

Alcohol as a poison. — C. F. Hodge, Professor of Physiology in Clark University, made a series of experiments upon four kittens and four spaniels. Moderate non-intoxicant doses of alcohol were given daily to two of each. The purring

and playfulness of the kittens dosed with alcohol gradually disappeared. At the end of ten days, they took severe colds. They were dwarfed in growth to 59, 63, and 39 per cent, respectively, as compared with the others. Of the two pairs of spaniels, the pair treated with alcohol weighed less, and developed only 71 and 57 per cent of the activity of the other pair, as shown by the pedometer. The dogs treated with alcohol also developed strange symptoms of timidity and fear, suggesting the terrible fears of delirium tremens and alcoholic insanity.

Decreased Physical Efficiency. — In Dr. Hodge's opinion the experiments above described have direct bearing on the question of the effect of alcohol on the human system. The experiments proved that *alcohol causes depression of activity.* For man the highest aim is to develop useful activity, the will, the determination to do as much of the world's necessary work as he is capable of doing, and to maintain a sound, vigorous body to enable him to carry out such determination. It is of the utmost importance, therefore, that we understand the conditions of our physical systems under which this great end can best be attained.

General Wolseley, of the British Army, found on experiment that those who did not receive alcohol were "fresher, livelier, and marched better than those that had alcohol." An experiment on typesetters in Germany showed that those who drank daily three fourths of a tumbler of wine were much less efficient than abstainers. Their work decreased on an average of 9 per cent. This means not only that the man could not do as much work, but also that his earning power would be less. On pages 46 and 323 it was shown how alcohol affected mountain climbing and marksmanship.

Decreased Mental Activity. — Memory is a very valuable quality of mind, and a good memory is not to be lost without regret. Dr. Smith showed in experiments that 70 per cent less work in memorizing figures was done when using alcohol

(Fig. 227). Professor Vogt showed in many experiments that the taking of one to three glasses of beer interfered with the memory process; that it took on the average 18 per cent longer to learn lines of poetry. In Italy, where a great

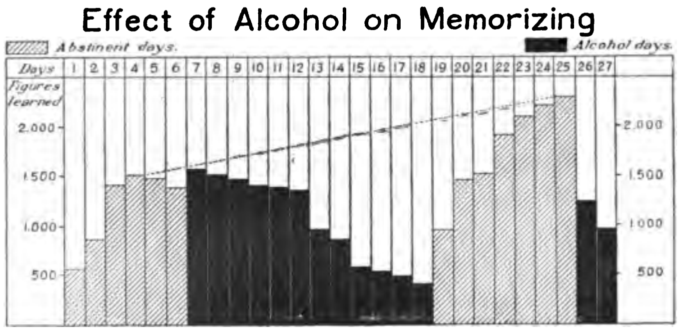


FIG. 227. — Height of columns represents the number of figures learned each day. Increase from day to day on abstinent days shows the gains made by practice. Decrease of fifth and sixth days due to temporary illness, and on the sixth day one dose of alcohol was taken. Dotted line from fourth to twenty-fifth days shows the normal rate of increase. Alcohol about equal to that in from two to four glasses of beer (40.80 grms.) taken on the alcohol days. Memorizing done eight or ten hours after taking the alcohol. Amount of work done on the twelfth alcohol day about 70 per cent less than it should have been, and was less even than was done on Day one.

deal of wine is made, it was found that the use of alcohol in this form even interfered with mental work in school. The following shows the report on 4000 children:

	462 ABSTAINERS	1616 DRINK WINE OCCASIONALLY	2021 DRINK WINE DAILY
	Per Cent	Per Cent	Per Cent
Good marks	42.56	30.5	29.8
Fair	53.49	41.8	39.7
Poor	3.85	27	30.3

Now alcohol renders the user liable to make mistakes. Consequently the managers of the Lackawanna Railroad,

after an accident caused by the engineer going past signals, made the following rule: "Trainmen must not drink or enter saloons even when off duty." This engineer had been drinking and the accident cost the death of 40 people and serious injury to 75 more.

Drink also causes more accidents to the worker himself. Hence, employers are demanding that workers shall not use alcohol. The following chart (Fig. 228) shows how difficult

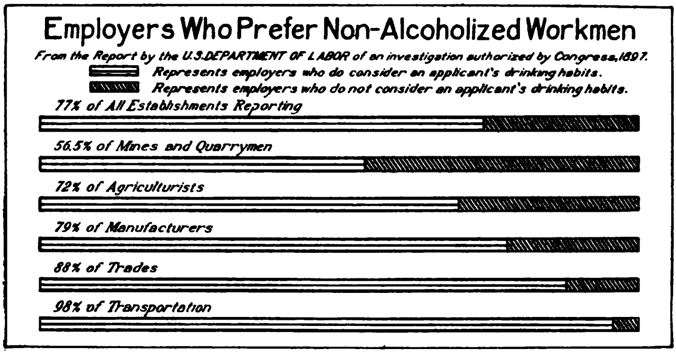


FIG. 228. — Drinkers are not sought as workmen or for responsible positions.

it is for the drinking man to obtain employment. It is harder for him to hold it, if he gets it, because he is less efficient, more liable to injury, and often causes trouble among other employees.

It is significant that great industrial organizations, railroads, and mercantile houses are requiring that their men do not drink. They know that alcohol in any form lowers the efficiency of their men and the men are beginning to realize that they are more capable and advance more rapidly if they leave drink alone. George Patullo writing in the *Saturday Evening Post* of the encampment of the National Guard on the Mexican Border says, "It is growing to be the same with the soldier as with every other calling. He finds that booze

does not pay, that it is a losing game and hurts his health. He has discovered that commanders frown on it and people with whom he would like to associate are temperate and prone to shy off from a hard drinker."

Insanity. — The sober man thinks first and then acts; the man under the influence of alcohol acts first and thinks afterward. Alcohol so interferes with the working of the mind (Figs. 229, 230) that the man is unable to make correct judgments. Consequently after a time his mind is really impaired. In the State of New York over 25 per cent of the insane in the hospitals of the state are insane because of the use of alcohol. It is estimated that there is lost to the State of New York every year, through insanity, over $2,400,000 and to the United States $12,000,000. The report of the states in which alcohol is not allowed shows a decrease in the insanity of that state. For example, the State of Kansas has made great improvement in this regard.

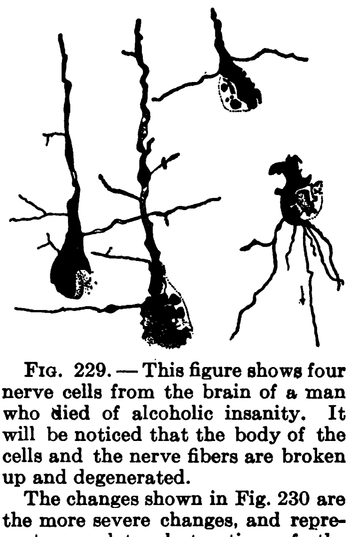


FIG. 229. — This figure shows four nerve cells from the brain of a man who died of alcoholic insanity. It will be noticed that the body of the cells and the nerve fibers are broken up and degenerated.

The changes shown in Fig. 230 are the more severe changes, and represent complete destruction of the nerve tissue.

Now at one time it was thought right and proper to drink, and in some places to-day drinking is a custom, a tradition that is followed. There are parents who drink alcoholic liquors because they formed the habit in their youth when drinking was considered less harmful than it is known to be to-day. *The one test of growth, in a people, is to make improvements from one generation to another.* So the child is not to judge the parent either as regards action or motive.

The new generation, better acquainted with the facts, many of them discovered recently, must see that it takes advantage of the facts and does not repeat the mistakes of the older generation. In this way civilization, in which we all have a part to play, will advance.

FIG. 230. — An illustration of the nerve branches and fibers in a case of alcoholic insanity. The patient died of this disease, and when the nerve fibers were examined under the microscope, they were shown to be swollen and broken down in the manner illustrated in the drawing. The swellings of the nerve fibers, as seen in this illustration, are characteristic, and are usually seen in the brain of those dying from alcoholic insanity.

Summary of the effects of alcohol. — In conclusion on this question it may be stated that the following represents the results of alcoholic drinks as a beverage:

1. Alcohol tends to reduce physical strength and endurance and the amount of work done.

2. It impairs mental work.

3. Alcohol belongs to the class of habit-forming drugs, like opium and morphine, which tend to create a craving for increasing amounts. In certain persons this leads inevitably to heavy drinking and its serious consequences.

4. The alcohol user on the average is especially liable to sickness and to premature death.

5. Drink increases liability to accident even in the person who is never intoxicated.

6. The use of alcohol by parents is often responsible for a high death rate in children, or for physical or mental defects.

7. Alcoholism does not necessarily mean drunkenness. The habitual user of alcohol may show some of its effects without ever reaching the stage of intoxication.

8. Alcohol is not a stimulant to the nervous system, but a depressant.*

9. Because of the effect of alcohol on mind and body it is responsible directly and indirectly in the United States for at least one fourth to one half of all poverty and neglect, for more than one third of pauperism, for one fifth of the insanity and divorces, and one half of the crime.

Tobacco. — The leaf of the tobacco plant is used for smoking and chewing. At one time it was used in powdered form as snuff. There are many reasons why tobacco should not be used by man, and no satisfactory reason why it should be used. With this viewpoint in the foreground there are some people who say that a person who uses tobacco is a fool and that he will go insane if he smokes cigarettes. Now such a statement is at variance with the facts. In condemning or praising any method or practice, care should be exercised in forming a judgment and discretion used in stating a belief. What does tobacco do to the cells of the body? How does it injure them? What may be the loss in terms of efficiency? These are questions that we should be prepared to answer.

General effects of tobacco. — In the first place we can think of men who are strong physically, keen mentally, and sound morally, who at times use tobacco. If they use it moderately, they may reply to our question by saying, "smoking does not hurt me." By such a statement one may mean that no perceptible harm is felt. *But, how much keener mentally, how much stronger physically, would he be, if he did not smoke.*

Smoking contributes nothing to a man. Men smoke but the smoking is not a characteristic of manliness. So, because you know men who smoke, do not think that smoking does not hurt them. Think rather of how much better in every way they would be if they did not smoke.

It is true that the use of tobacco forms a habit that tends to increase the amount of tobacco used. This is the special danger in cigarette smoking. It leads frequently to the use of so many cigarettes that health and strength are lost.

That smoking causes undesirable effect upon the body is shown in the custom of college athletes. Coachers and trainers do not permit smoking by those who play on the team and all athletes who seek to excel in sport, do not use tobacco.

We know that smoking impairs one's physical efficiency. A war correspondent visiting the Italian trenches in the Trentino during the recent war writes as follows:

"As we pushed on, all our old sins of pipes and cigarettes began to be expiated in our middle-aged hearts. . . . So we struggled on, the easy perspiration bathing our bodies. Hiatt was doing better than I, being younger and less guilty of cigarettes. I would force myself until I could go no farther; would stop; would droop over my alpen-stock and pant like a netted fish."

Men who smoke to excess find that they become nervous, lose their appetite for wholesome food, and show a distinct loss in efficiency.

The effects of tobacco upon youth. — The youth who looks forward to physical efficiency as well as mental efficiency as important factors in doing a work and achieving a place in the world, will leave tobacco alone. The growing boy suffers the most of all from the use of tobacco. His growth is interfered with, his heart is injured, and his stomach disturbed. If the boy thinks he wants to smoke, he should wait until he is twenty-five years old; then with developed

body and a wiser mind, if the use of tobacco seems desirable, let him make the choice, cognizant of its dangers and limitations. *The youth who looks forward to excellence in athletics, to achievement in business or the professions, to authority and control in store and factory, will select his habits as carefully as his friends, his food as carefully as his facts, and he will leave tobacco out of the things that are for him.*

APPLIED PHYSIOLOGY

1. Should a person with a "cold" keep away from other people?
2. What is the value of vaccination? Are you vaccinated?
3. Do you take reasonable care to see that your food is fresh? Is this important? Can ill health result from decayed food?
4. What diseases may flies carry? How is your home protected against flies?
5. How many hours a night do you sleep? Does it satisfy the requirement? What is the requirement for your age?
6. Do you wash your hands before eating? In what diseases is this habit very important?
7. Do you sleep at night with your windows open? In winter?
8. Do you attend to the elimination of the body waste every day? How important a habit is this?
9. Are bacteria destroyed within the body?
10. Which is the most important, prevention of infection, or disinfection after infection has resulted from carelessness?
11. Is cleanliness of value in the home? How much more valuable is it in the person?
12. How many Health Rules for Children do you know and follow?
13. Is alcohol a food? How did the Russian government solve the question?
14. What is fatigue? How can you tell when it is time to rest?
15. Are stimulants advisable when you are tired? What will rest do that stimulants will not do? Is restoration of more value than stimulation?
16. What is the difference between natural and artificial stimulants?
17. Write an essay on alcohol with reference to its impairment of the efficiency of the body.

GLOSSARY

Benzine. — A colorless and highly inflammable liquid obtained from crude oil by distillation.

Depressant. — A substance that lowers the irritability of the body cells, and makes it difficult for them to respond.

Opiate. — A substance allied to opium and capable of inducing sleep.

Sedative. — A medicine having the power to quiet and sooth the body.

Strychnin. — A white crystalline poisonous compound with the formula ($C_{21}H_{22}N_2O_2$). It is a strong stimulant of the nervous system and highly poisonous.

APPENDIX

FIRST AID IN EMERGENCIES

Artificial respiration. — This is a means for getting air into the lungs of a person after drowning, smothering, gas poisoning, and the like. It is a rather simple procedure and not so complicated as a young friend of the author seemed to think when she called it "agricultural perspiration." It is performed in the following way (Schaefer Method). Place the subject face downward on the ground, turn the face to one side, and bring the hands to a resting place beside the face. Kneel astride the body of the person and place your hands on each side of the back in the region of the lower ribs. You are now ready to begin. It must be remembered that the average rate of respiration is about 18 times a minute and the procedure you are to follow should proceed at about the same rate. (1) Lean forward on your hands so that all your weight may be brought to bear on the ribs of the subject. This forces the air out of the chest. (2) Raise your body and release the pressure on the ribs. The elastic chest wall will fill out and take in air. This pressure and release at the rate of 18 times a minute will cause the air to pass in and out of the lungs and so will provide for the necessary oxygen.

Inasmuch as the most frequent cause for the use of artificial respiration comes from drowning, it is important to know and remember the proper care regarding accidents on the water. If the boat or canoe upsets, the first efforts should be directed to getting hold of the side of the upturned vessel. A boat or canoe will float and will support the weight

of several persons. After support is obtained, then one may look around to see what is the desirable thing to do. In many cases other people will see you and come to your assistance. Their assistance is often too late if the one having the accident has thrown himself around in the water, has called out, and has taken a lot of water into the mouth causing choking and making breathing difficult. Do not cry out as the boat upsets, for you are liable to choke with water taken in with the mouth open.

Black eye. — A blow in the face, by bruising the soft tissues around the eye, may cause discoloration. The best treatment is the immediate application of an ice pack (chipped ice in an ice bag) or cold compresses applied every half hour. If this does not entirely prevent the discoloration, the part may be painted by a face paint but usually this is unnecessary. Beefsteak serves no valuable purpose in this injury when applied to the part.

Burns. — Burns are of different degrees of severity depending upon extent of the burn in area and in depth. The depth of the burn is described as follows: The first degree shows a reddening of the cells of the epidermis; the second degree shows a separation of the epidermis from the dermis, with the formation of serum between the two layers (blister); the third degree shows the destruction of the epidermis with some burning and injury in the dermis.

After the burn, be it from heat, chemical, or other source, do not touch the part burned with the fingers, do not apply salve of any kind, and do not open any blisters. The best first-aid dressing is the application of the following on a sterile gauze dressing:

Picric acid	65 grains
Alcohol	2.5 ounces
Distilled or sterile water	1 quart

This solution is made by dissolving the picric acid in the alcohol and then adding the water. Do not remove the

dressing for three days if the above precautions have been taken. If, however, the above dressing is not available, baking soda may be applied directly to the burn and the wound then covered with a sterile bandage. On about the third day, blisters may be opened with a needle after its tip has been heated in a flame to a red heat (a match may be used for this purpose). Burns which do not blister are not dangerous and they may be treated by applying sterile vaseline.

Broken bones. — A broken bone is a fracture of the bone. In case of such accident keep the patient quiet. If he must be moved, a splint for the part may be made by means of a shingle, umbrella, pillow, or folded newspaper. Send for the doctor. If the end of the bone projects through the flesh, do not touch the wound but cover it with a sterile bandage.

Cuts and wounds. — Keep the cut or wound clean (Fig. 231). This does not mean putting some so-called antiseptic on it to clean it, but it means in most cases putting nothing on it but a sterile

FIG. 231. — Boy Scouts giving first aid treatment to a comrade.

dressing. If there is dirt in the cut, painting the area with tincture of iodin will be good treatment. Hydrogen peroxide and other first-aid remedies are less valuable. Protect the wound from anything that will infect it as fingers, clothing, or other objects, and help it to heal by keeping the part at rest. If the wound bleeds severely and the blood does not clot, pressure (see hemorrhage) may be applied above the wound (Fig. 232).

If the wound does not bleed freely, as in the case of pin pricks, injuries from nails and other sharp instruments, every effort at first should be directed toward causing free bleeding. Tincture of iodin on the end of a tooth pick wrapped with a small amount of cotton, should then be inserted in the wound. If this treatment does not effect a cure in one day a surgeon should be consulted.

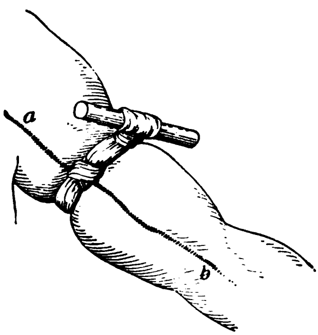


Fig. 232. — The method of applying the knotted handkerchief to compress a divided artery. *a*, *b*, track of the inner artery of the left arm.

Fainting. — The practice of throwing a bucket of cold water on the person who faints is not to be approved. If the person is reclining, let him lie and keep the head lower than the feet. Loosen all tight clothing and gently fan the person or bathe the brow with cold water. Never give whisky to a fainting person. Keep people away, allow plenty of air, and maintain quiet. After the attack, do not move the person for at least half an hour.

Foreign body in the eye. — Cinders or dust particles in the eye are best removed with the tip of a handkerchief. If the object is on the upper lid, the lid must first be everted. This is best done by asking the person to look down at the time you are folding the lid back over a pencil.

In many cases it is necessary to have the services of a physician.

Foreign body in the ear. — In removing objects from the ear, care must be taken not to put any instrument in the ear. Children sometimes put such things as peas, grains of corn, etc., in the ear. They can be removed by washing out with an oil; do not use water because that will make the grain swell. Insects should be killed by oil and then they can easily be washed out.

Hemorrhage. — Hemorrhage is bleeding from a part, but this term is not used in the case of simple cuts. Where the flow is marked, the term hemorrhage is more aptly applied. In nose bleeding from an injury, keep quiet and compress the nostrils, breathing through the mouth. Often the nose bleeds from picking the nose with the finger nail. It is important not to pick the nose in such manner, and such bleeding usually comes from an ulcer caused in this way. Such an ulcer may need to be cauterized by a physician.

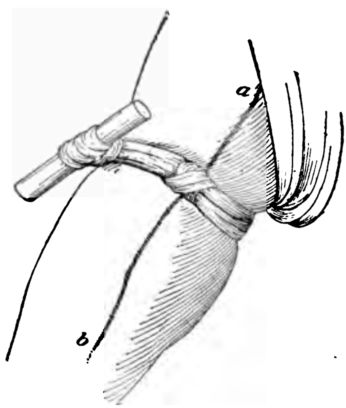


FIG. 233. — *a*, *b*, the track of the right femoral artery; the compress applied near the groin.

Bleeding from the lungs gives frothy blood. Do not be alarmed but keep the patient absolutely quiet. Send for the doctor.

Bleeding from the stomach usually shows in vomiting and the blood has a black appearance like "coffee grounds." Send for the doctor.

Bleeding from the bowels occurs usually in case of piles. Keep quiet, avoid cathartics, and consult the doctor.

Bleeding from other parts of the body following an accident

is best controlled by applying with pressure a pad of sterile gauze and holding it in place with a bandage. If this fails, pressure above the bleeding point may be performed but in most cases this is unnecessary. The application of such pressure is to be made over the artery going to the part and by means of a handkerchief loosely tied around the part and then twisted tightly with a stick (Figs. 232, 233).

Sprains. — The spraining of a joint is due to a twist or fall. If the injury is cared for at once the best treatment is to immerse the part in ice-cold water and keep it there for fifteen minutes. If the injury cannot be cared for at once, the subsequent treatment is the application of heat in the form of hot water. In either case, afterwards the part should be strapped properly and the patient allowed to use the part. Bad sprains should be treated by a physician because there is often a break in one of the bones entering into the formation of the ankle joint.

Poisoning. — The elaborate tables of the common poisons with their symptoms, antidotes, and treatment are of little use because they are too long and difficult to memorize and they are not available, as a rule, when most needed. The principle may be taken as a general rule: if the poison is an irritant that destroys tissues such as acids, lyes, metallic poisons, etc., give to the patient the raw whites of several eggs. First, however, send for the doctor. If the poison is of another kind, a narcotic, such as chloral, alcohol, cocain, laudanum, then make the patient vomit. Vomiting may be caused by giving a teaspoonful of mustard in a glass of warm water. This may be supplemented by more warm water and by tickling the back part of the throat with the finger.

In poisoning, there is always depression of the vital powers, so keep the patient quiet, apply heat externally, and, if necessary, give artificial respiration. External heat may be provided by blankets, hot water bottles, or heated stones applied to the body.

FIRST-AID REMEDIES TO HAVE IN THE HOME

Sterile gauze	
Bandages of one and one half inch	
Alcohol (grain)	
Tincture of iodin	
Adhesive plaster, one inch wide	
Powdered boric acid	
Aromatic spirits of ammonia	
Picric acid for making the solution for burns	
Sterile vaseline in tubes	
Chlorazene surgical cream . .	4 ounces
Castor oil	4 ounces
Seidlitz powders	1 box of 12
Mustard, powdered	2 ounces
Syrup of ginger	2 ounces
Syrup of ipecac	2 ounces
Talcum powder	1 tin
Clinical thermometer . . .	1
Red Cross first-aid packets . .	3

Uses of these remedies. Sterile gauze. — This is used to cover open wounds. There must be care in handling so that

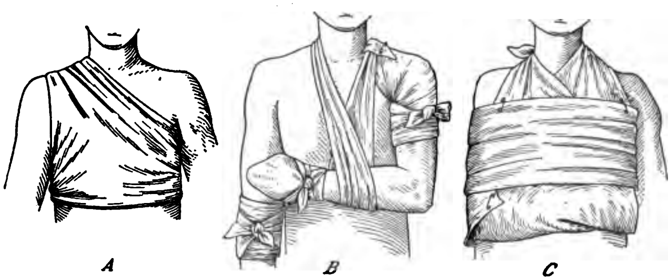


Fig. 234. — Various forms of handkerchief bandages: *A*, for the chest; *B*, for the shoulder, hand, and arms; *C*, double bandage to prevent motion of the arm.

it is not contaminated. The hands should touch only a corner and in no instance should they touch the part applied to the wound.

Bandages. — They are used to hold the gauze in place, or give support to an injured part (Figs. 234–242). They may be used for sprains and with splints for broken bones.

FIG. 235. — Handkerchief bandage for perineum and hip.

FIG. 236. — Three-cornered bandage for arm.

FIG. 237. — Four-corner bandage for arm.

Alcohol. — Used externally in sprains, strains, and bruises. May be used for massage or rub.

Tincture of iodin. — Used on wounds to kill the bacteria. May also be used as a counter-irritant in sprains and strains.

Adhesive plaster. — Used to give support to an injured part.

Boric acid. — A saturated solution is valuable for cleansing and soothing the conjunctiva of the eye. Used after being exposed to wind and dust or in mild infections of the eye.

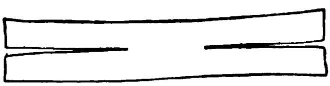


FIG. 238. — Four-tailed bandage.

Aromatic spirits of ammonia. — For fainting, shock, or marked depression, it serves as a stimulant. One teaspoonful in a half glass of water is the dose. It may be repeated.

Picric acid. — For burns. (See page 418.)

Sterile vaseline. — Vaseline may be used in all wounds so that the dressing will not adhere. It should be sterile.

Chlorazene surgical cream. — Superior to vaseline because of its disinfectant powers, it should be used on infected wounds. It is very valuable.

Castor oil. — This is a mild cathartic. Dose for adult, 1 tablespoonful; for child 6–12 years, 1 to 2 teaspoonfuls; for infant, ½ to 1 teaspoonful.

Seidlitz powder. — Mild purge for headache, and symptoms of constipation and sluggishness of excretions.

Mustard powder. — Used to provoke vomiting by giving a teaspoonful in a glass of lukewarm water. May also be used in mixture with flour (4 parts mustard and 7 parts flour) for a mustard plaster in bronchial and throat conditions.

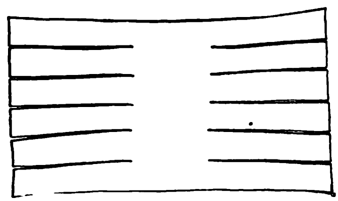


FIG. 239. — Many-tailed bandage.

Syrup of ginger. — One third teaspoonful in a glass of water is used for cramps and diarrhœa.

Syrup of ipecac. — One teaspoonful used with children to produce vomiting. Valuable in croup because it increases the secretion in trachea and lessens the obstruction.

FIGS. 240 and 241. — Four-tailed bandage for the head.

FIG. 242. — Four-tailed bandage for the jaw.

Talcum powder. — Used in sunburn and for drying and soothing action on skin.

Red Cross first-aid packet. — This outfit contains a gauze bandage, a triangular bandage, and two safety pins. The gauze and triangular bandage are arranged to permit

application to wound without danger of contamination. It is very valuable for those who are unfamiliar with the handling of sterile equipment.

EQUIPMENT FOR AN EMERGENCY ROOM IN A PUBLIC SCHOOL

- Furniture
  - Two couches (rattan)
  - One table
  - Two chairs (wood)
- Closet
  - Four woolen blankets
  - Two hot-water bags
  - One ice bag
  - Two granite basins
  - One dozen clean towels
  - Splints for broken bones
- Medicine case
  - Aromatic spirits of ammonia
  - Toothache plasters
  - Bi-carbonate of soda
  - Picric acid (65 grains)
  - Alcohol (grain)
  - Mustard
  - Olive oil
- Surgical case
  - Sterile absorbent cotton
  - Sterile gauze
  - Sterile bandages
  - Zinc oxide adhesive plaster
  - Sterile vaseline in tubes
  - Tincture of iodin
  - Dressing forceps
  - Surgical scissors
  - Safety pins
  - Book on the treatment of emergencies

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L O E

T A E

Y F E V

PLATE X. SNELLEN

R B G

N L V

O T P D

EYE TEST CHART